REAL THINGS IN NATURE

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Real Things in Nature

A READING BOOK OF SCIENCE
FOR AMERICAN BOYS AND GIRLS

By

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PREFACE

THE immediate object of this volume is to present to young children a view of the world which shall be, in its degree, complete, useful and interesting.

An American lad of a dozen years of age has had training at home and at school; he has observed the world for himself, and has profited more or less by the experience of his fellows. He has ideas upon many subjects; he is forming habits of thought that will be of the greatest consequence to others and to himself in the future. He is just at the time of life when his mind is open to direction, and is eager for explanations of the world in which he lives. He is full of questions. The various parts of this volume give the answers to such questions.

For example: the American school boy is familiar with railways, electric lights, the telegraph, the telephone, etc. He has many questions to ask concerning them, and concerning the machines that he sees in daily use — the lever, the balance, etc. The answers are given in the book on Physics.

Every American boy is interested in the habits of animals and has met in his own experience many instances of their intelligence. He listens with interest to accounts of their social organizations, and to explanations of their adaptations to environment and circumstance.

It is not possible to give complete explanations; but it is not difficult to have the explanations complete so far as they go. He will have nothing to unlearn in the future; on the foundations here laid in these and other subjects he can go as far as he likes.

Certain scientific ideas are entirely too difficult to be grasped by young minds. It is better to omit some topics altogether than to present a set of words which can have no vital meaning. Very much of chemistry, for example, is above the capacity of young pupils. All that can be done is to present a few fundamental ideas, to enforce them by a few simple and safe experiments and to leave the rest of the science untouched.

It is the fundamental ideas of science and its *methods* that are here insisted upon; its *facts* are of importance chiefly as illustrating its mode of thought. The methods of astronomy, of geology, of chemistry, for example, are very different. The answers to the questions: How do you know that the stars are self-luminous? How is it proved that water is compound? How is the age of the Earth determined? are reached by very different paths. It is of the first importance that the pupil should know how his elders set about to prove such things. He should carry away from his reading an intimate conviction that such answers have malia, etc., he understands what he has studied. There is no better test.

There can, of course, be no originality in the subject matter of an elementary book of this sort. The chief merit which can be hoped for is a clear presentation of well-known facts. It is possible to make great subjects interesting to both teacher and pupil, even where they must be treated with extreme conciseness. If, as is hoped, this has been done, the volume should be of value. If America is to take and maintain a foremost place in the world, it can only be done through the predominance of certain qualities in its citizens that scientific education fosters to a very important degree. We cannot afford to neglect any means of developing thoroughness and faithfulness in the performance of duty in those who will soon be the responsible governors of our country.

Every year thousands of children leave the public schools to begin life for themselves. Only a small percentage enter high schools, and a very much smaller percentage enter colleges. It is the duty of the common schools to prepare their graduates as fully as possible for the business of life. They must be thoroughly grounded in the elements of knowledge. What more can be done under the circumstances? Some of the workings of the world around them can be explained. They can be made to understand the fundamental notions of government, law, history, science. They can be taught to reflect on what they see and hear.

It is believed that a book like the present volume in the hands of the zealous and intelligent teachers of the country will be a suggestive help in all these matters. Under the most favorable conditions the pupil will have been taught what it contains in his own home. In many cases he must depend upon formal instruction at school. To aid formal instruction of this sort, to systematize it, is the main object of the book. Its ultimate purpose is fully explained in the introduction that follows.

E. S. H.

U. S. Military Academy,
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June 17, 1902.

TO MY YOUNG FRIEND

KATHARINE TILLMAN

really been found. and that, on the whole, he knows *how* it was done, although he may not know all the details of the processes.

The experiments here described are, with very few exceptions, such as can be performed by the teacher in the class-room or by the pupil at home. In general, it is a mere waste of words to describe an experiment that requires complex apparatus which the pupil will never see except in the figures of his text-book. Simple experiments are here suggested, and the pupil is reminded of verifications that he himself can make by the words (try it)--which occur very frequently in this text.

The main object is to teach *ideas*. Technical words are avoided so far as possible. At the same time technical terms have been unhesitatingly employed when they are essential to [illegible] or when they are such as will be constantly met with hereafter. It is necessary to say *protoplasm*, for instance; there is no royal road round it.

The book is designed to supplement the instruction which the pupil has gained from other text-books and to carry it further, according to a symmetric plan. It is occasionally necessary to treat subjects here that have already been studied by the child in his Geography, History, etc.; but it will be found that the old topics are approached in new ways, so that there is no real loss of energy or time.

Sometimes the same topic has been treated twice, from two different points of view, in two different sections of the book. New relations of familiar things are thus disclosed; and this method would have been followed oftener had the limits of space permitted.

The illustrations have been carefully chosen, usually from books published by the Macmillan Company, especially: Huxley's Physiology, Bailey's Botany and Lessons on Plants, Davenport's Zoölogy, McMurry & Tarr's Geography, Tarr's Geology and Physical Geography, etc., etc. To these and other authorities the writer's obligations are gratefully acknowledged.

The titles to the cuts are usually given in two parts: first, a short title which the pupil will remember; second, a longer explanation which makes the cut complete in itself and saves a reference to the text. The pictures in the book, with their titles, constitute an abstract of the whole work. When the book is used in the class-room the pupil should be instructed to point, with a long pin, at each part of a cut as he reads its explanation in the title.

[illegible] a cut in the book is understood the pupil should, in many cases, be required to draw it from memory. If he can reproduce such cuts as those giving the [illegible] of shadows, the connections of an electric bell, the genealogical tree of the mam-

INTRODUCTION.

(TO BE READ BY THE CHILDREN WHO OWN THIS BOOK.)

THE children who read this book ought to know before they read it what use it is going to be to them. Let us see. The book is owned by an American school boy (or school girl) who was born ten or twelve years ago and who expects to live in this world fifty or sixty years more. Fifty years is a very long time — think of all the things that have happened in the last fifty years — and then think forward what may happen in the next fifty years — things that may happen in the world, in this our country, or to you.

Suppose that we could make things happen by merely wishing them, what would you and I [illegible] for the whole world? We should begin by [illegible] that there might be peace and plenty—no wars, no famines, plenty of work for all of us, a chance for every one, and a wish in every one to do his [illegible] What we desire for the whole world in general, we particularly wish for our own country. We hope its future will be peaceful, that there will be no quarrels or wars, that every man can always find work to do, that every one of us will wish to work and will do his work faithfully and cheerfully.

Your best friend will wish the same thing for you that we have wished for the country. He will wish that your whole life shall be peaceful and happy, that whenever you need money for yourself or for your family and friends you can find plenty of well-paid work to do and that you will wish to do it faithfully and with all your might, that you will always try to do the right and useful thing cheerfully.

If these wishes come true you will lead a happy life, you will be useful to your country; and if all the school children are like that, your country will be useful to the whole world and honored everywhere. Something depends on you, then; you can be useful to your friends and family and country if you will try; and if you try, you will be happy yourself. If enough of us try we can make the country useful to the whole world. But we must try in the right way; we must know what to do and how to do it.

We must understand things and the reasons of them—what they are and why they are. Not to understand is like trying to work in the dark. The better you understand the reasons, the better work you can do, and the happier you will be in doing it.

For instance, just suppose that one of the boys in a school grows up to be the engineer of a locomotive. All engineers understand their business very well, but some understand it a little better than others. Any engineer can run his engine safely so long as all the machinery works well. Some day, in spite of everything, there is danger of an accident. The man that knows his business best is most likely to take his train safe through. Because he understands he is able to save his train and, it may be, to save people's lives. That is worth doing. It is worth while to understand.

This book teaches every boy something about the locomotive. If he understands what is taught here he can easily go on and learn more. It teaches him about electricity, too, so that he will know how the telephone carries the voice from place to place; why it is possible to telegraph from New York to San Francisco, or under the ocean to London; how it is that electric cars are made to go; and a hundred other things of the same sort.

In a small book like this it is not possible to speak of everything; but the most important machines and inventions are explained. By paying attention you can understand these, and if you thoroughly understand one machine you can learn about others. While you are learning you are fitting yourself to be a more useful citizen. The man that understands is the man that everyone trusts. He has the work he wants and is well paid for it. He likes his work. It is a pleasure for him to do it. Many of the chapters in this book speak about just such practical things as the locomotive, the telegraph, etc.

Some of them speak about matters that do not seem to be practical at all, about things that are not immediately useful—about the motions of the Sun, Moon and Stars, for instance. You may say, what earthly good can it be to me to know that the Stars rise and set, as the Sun does; or to know what makes the colors of the rainbow; or to study about the chemistry of sulphur and carbon and nitre?

Here is an answer to one of these questions; and all of them have answers of the same sort. It is extremely "practical" for ship captains to be able to navigate their vessels safely and quickly from port to port. The navigating of vessels is done by the stars. The first thing for a captain to know is that all the stars rise and set. He has to begin with that. Afterwards he finds out the latitude and the longitude of his ship by measuring the height of the sun and stars above his horizon at certain times every day. If he knows his latitude and longitude he knows where his ship is on the trackless ocean. That is "practical." It would be very unpractical for a ship captain to arrive at Brazil when he meant to go to England. But that is the very kind of thing he might do unless he began by learning what is taught in this book about the stars.

Gunpowder is made by mixing charcoal and sulphur and nitre; and it is made according to the rules of chemistry. It is practical and useful to be able to make good gunpowder, so that rocks can be quarried easily, tunnels hollowed out, cannons fired, and so forth.

Moreover, it is interesting to know such things. Here you are living in a world full of interesting things—sunsets, rainbows, machinery, and so forth. Why not learn about them?

Suppose some one working in a factory saw a steam engine driving the machinery every day and all day, and never took the trouble to ask how it was that a little coal put in a boiler downstairs made a wheel turn round in the fourth story. It would show, in the first place, that he was not very much interested in his work, and in the second place that he was rather stupid not to find out how a coal fire could be used to heat water to make steam; and how steam could be made to turn a wheel on the engine; and finally how belts on this wheel could be made to turn all the wheels in a whole building. Suppose a boy never tried to find out what made the hands of his watch turn round so as to tell the time. It would be stupid for him to call it magic, and not to try to understand.

Now the whole world can be explained. It is not magic. There is a good reason for everything. Some of the reasons are not easy to find out but many of them are. This book explains some of the simplest and most interesting and important things. When you have thoroughly understood these you can understand others either by looking about you and thinking for yourself; or by asking questions of older people; or by looking in encyclopædias and other books of the sort. When you understand, you can be useful; and when you are useful you will be happy. The business of grown-up men and women is to *do useful things;* the business of children is to *learn how to do them.*

This book is written, then, to help you to understand the world you live in; to put you in the way of being a useful citizen; to help you to be happy. Every intelligent American child, boy or girl, ought to know all that is in this book (and a great deal more). Things that are explained here will help you, every day, to understand the world you live in. It is *your* world (whose else is it?). Why shouldn't you take the pains to understand it? The difference between men and animals is just that men are interested and do understand while animals take everything for granted and do not even try to understand what they see.

The boy that tries to understand turns out to be the most intelligent man; the most intelligent man can be the most useful and the happiest; the nation that has the most intelligent citizens is the most useful nation in the world. You have a share in this work and this book is written to help you to do your part.

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The air and the coal-gas that is burned to give light in street-lamps are gases. Gases are usually invisible. You cannot see the coal-gas, but you can hear it rushing out of the opened burner, and when you touch it with a lighted match it burns. You cannot see the air you are breathing but it is there, just the same. The wind is nothing but moving air; and you can feel the wind. Clouds float in the air just as corks float in water. A balloon floats in the visible air.

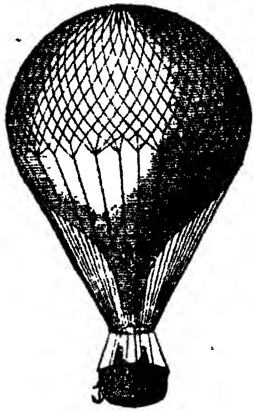


FIG. 39. A ball floats in the air somew as a cork floats in water.

Ice is a solid; melt it, and it becomes a liquid; the water is just the same thing as the ice—the same thing in a different form. You can freeze the water again, if you like, and have ice, once more. Or you can take the liquid water, heat it in a tea-kettle and boil it all away into steam. *Solid* ice, *liquid* water, *gaseous* steam, are three different forms of the same thing.

Real steam is invisible, as you could tell if you boiled water in a glass tea-kettle, You would see the water and nothing else though the steam would be there, filling the kettle above the water. The little clouds of vapor at the spout of a tea-kettle are not clouds of gaseous steam, but extremely small drops of liquid water. They look white just as the little drops of spray from a fountain look white. Both the fine spray of the fountain and the fine bubbles that make the clouds at the spout of a tea-kettle are water and only water. By pressing and freezing air it can be made liquid and even solid.

Force of Gravity.—If you drop a stone from your hand it falls to the ground. Anything—lead, iron, stone, wood—falls when you let it go, and it keeps on falling till it reaches the ground, or until it is stopped by something—by a table, or something of the sort. Every heavy thing falls as far as it can. And everything that you know of is heavy. Paper is heavy; it has weight. (The Latin word for weight is *gravitas*=heaviness.) A newspaper crumpled up into a ball has the same weight as the same newspaper loose in sheets. If you let the loose newspaper fall

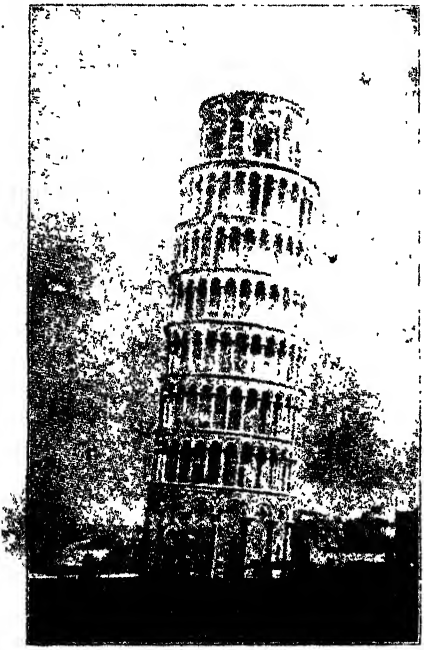


FIG. 40. The leaning tower of Pisa. This tower was built about A. D. 1200, and is still to be seen, as in the picture.

from a second-story window it will flutter about and take a long while in falling; but if you crumple it up tight it will fall to the ground in just the same time as a stone dropped at the same moment. (Try it.)

Fall of Heavy Bodies.—Drop a heavy stone and a lighter one from the second story window at the same time and you will see that both of them reach the ground at the same instant. (Try it.) For thousands of years men thought that a heavy stone would fall quicker than a light one, but Galileo[1] tried this experiment from the leaning tower of Pisa[2] and proved that all things, heavy or light, fall with the same quickness.

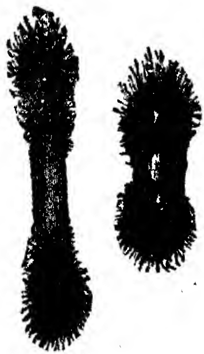


FIG. 41. A magnet attracts bits of iron near it. (The experiment should be tried.) There is something about the magnet that draws the iron; there is also something about the Earth that makes things fall. There is a force in the magnet, and a force in the Earth.

Ten pounds of loose feathers float about in the air for a long time. The air blows them about. But if you put them in a tight bag they fall just as fast as ten pounds of ice, or water, or lead; just as fast, and no faster, than one pound of lead, or ice, or water.

Attraction of the Earth.—Why do these things fall down? Why do they not rise up? The answer is: They fall

[1] Pronounced gal-ĭ-lē'ō. He was born in Italy in 1564, and died in 1642.

[2] Pronounced pē'zä. A city of Italy.

because the Earth attracts them—somewhat as a magnet attracts a piece of iron. (Try it.)

The weight of a horse walking presses on the ground and makes deep footprints. The heavier the horse the deeper the footprints. If you hold a stone by a string as in the picture of the pendulum (Fig. 13) the weight of the stone pulls on the string. The heavier the stone the more it pulls. A large stone pulls twice as much as one half as large. If you fasten the stone to a spring-balance, you can measure how heavy it is—one pound, two pounds and so forth. What you are measuring is how much the Earth is pulling the stone downwards.

If you throw the stone in the air it goes a certain distance upwards but it always falls. The Earth is always attracting the stone; it is always attracting apples downwards from the trees when they are ripe the stems are weaker and the apples fall): it is always pulling down the mountains by attracting the rocks and making them fall; always, day and night, making the rivers flow down hill. After a stone has fallen as far as it can go and is lying flat on the ground, the Earth still attracts it. Try to pick it up and you will see that the stone still has weight—that the Earth keeps on attracting it, somewhat as a magnet holds fast to the bits of iron it is attracting.

How Fast do Things Fall?—All heavy things fall at the same rate; one falls just as fast as another. By dropping things from high towers and timing their fall by a watch, it has been found that

All heavy things fall 16 feet in the first second,
" " " " 64 " " " " two seconds,
" " " " 144 " " " " three seconds,
and so on.

You can prove a part of what has just been said if you can find two windows one 16 and the other 64 feet from the ground. A stone dropped 16 feet takes one second (by a watch) to reach the ground. A stone dropped 64 feet takes two seconds. If you have no watch you can make a pendulum that swings in just one second by taking a string $39\frac{1}{10}$ inches long and tying one end to a nail and the other to a weight (a key will do):

One swing of the pendulum of Fig. 13, from any point back to the same place again takes two seconds. One boy can drop the stones and another can count the swings—the seconds. (Try it.)

Weight.—The government keeps a piece of metal in Washington which is called a *pound* weight; and there is a law that all the pound weights in the whole country from Maine to California shall be alike.

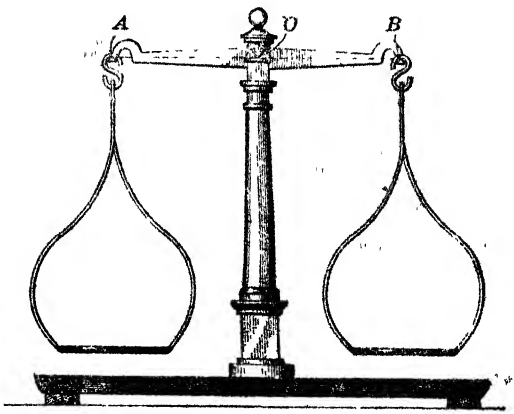


FIG. 42. A balance. If you put two weights that are alike in the two pans, the arm (*AB*) will be level. If one weight weighs more than the other its pan will go down. You can make a weight like another weight, then, by filing it down till the two just balance.

One-sixteenth of a pound is called an *ounce*. All the ounce weights of all the druggists in the whole country are alike. If you have a balance, and the weights that go with it, you can weigh anything you choose. A pound of anything must just balance the pound weight.

Notice that a pound of lead is smaller in size than a pound of iron; *lead is heavier than iron* we say--and we mean that a cubic inch of lead weighs more than a cubic inch of iron. Notice that a pound of soap is bigger than a pound of iron; *soap is lighter than iron,* we say--and we mean that a cubic inch of soap weighs less than a cubic inch of iron. Your body is a little lighter than water; and the proof is that if there were a hollow glass statue exactly of your shape and size, filled with water, the water in it would weigh more than you do.

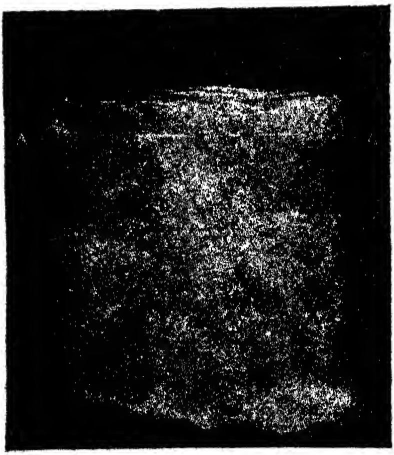


FIG. 43. Photograph of a piece of floating ice. The level of the water is along the line *A* ....*A*.

Another proof is that you can float in water. Your body is lighter than lead; and the proof is that if there were a lead statue exactly of your shape and size it would weigh much more than you do.

Ice is lighter than water; it floats.

Gold is 19 times heavier than water;
Quicksilver is 13⅓ times heavier than water;
Lead is 11 times heavier than water;
Copper is 9 times heavier than water;
Iron, Tin, Zinc are 7 times heavier than water;
Common stone is 2½ times heavier than water;
Ice is $\frac{9}{10}$ as heavy as water;
Oak wood is $\frac{7}{10}$ as heavy as water;
Kerosene oil is $\frac{7}{10}$ as heavy as water;
Cork is $\frac{2}{10}$ as heavy as water.

Notice that things that are heavier than water sink when they are put into it; and that all things that are lighter than water (ice, wood, cork, etc.) float. Iron will float on Quicksilver. (Try it.) The air is much lighter than water (and so all air-bubbles rise in a tumbler of water). The air in any box weighs only one one-thousandth as much as the water that would fill it.

The Vertical Line; Up and Down.—The Earth attracts all heavy bodies somewhat as a magnet attracts every piece of iron. All heavy bodies fall down as low as they can. Fasten a string to a nail and a weight to the other end of the string. The string points *up and down*, we say. It is a vertical line. *Up* is towards the nail; *down* is towards the Earth. Wherever you may be a pendulum at rest is vertical—is up and down.

Now the Earth is round, and as you travel round the Earth you will have a vertical line at each city, but a different vertical line at different cities.

Up then really means away from the center of the Earth; *down* really means towards the Earth's center. A vertical line is really the line of that diameter of the Earth which passes through your feet. The point in the sky, among the stars, over your head is called your Zenith-point. The four boys in the picture have four different zenith-points.

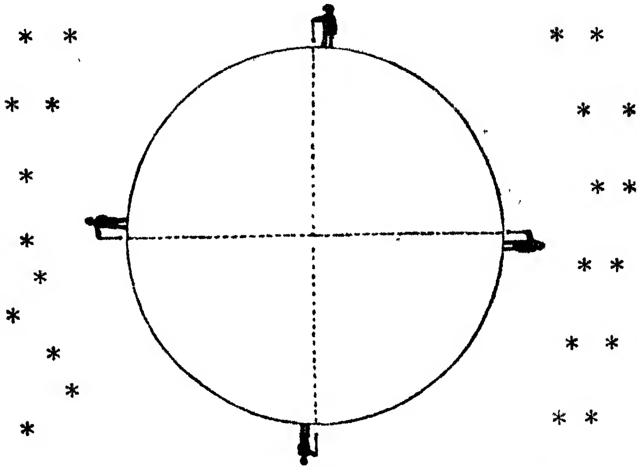


FIG. 44. A pendulum at rest anywhere on the surface of the Earth points to the center of the Earth.

The Sun attracts the Earth and all the planets just as the Earth attracts everything in its neighborhood. Everything on the Earth is held near it by its attraction, just as all the planets are held near the Sun by its attraction.

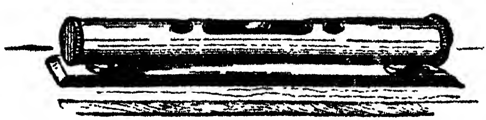


FIG. 45. A level somewhat like the levels used by carpenters. When the little air-bubble is in the middle of its tube, the straight-edged board is level—is horizontal.

The vertical line is perpendicular to the level surface of the ocean, or to the level surface of still water anywhere (hold a pendulum over a basin of water and see for yourself). Masons use a pendulum swung in a board to get their brick walls vertical, and carpenters and surveyors use levels—which are glass tubes almost filled with alcohol—to get their lines horizontal, or level.

Measures of Length—a foot, a yard, a mile.—The government keeps a bar of metal in Washington and the distance between two particular lines on that bar is called a *foot*. Three feet make a *yard*; 5,280 feet make a *mile*. Twelve *inches* make one foot. There is a law that every foot-rule in the whole country, from Maine to California, shall be of one and the same length. Every carpenter's foot-rule is just the length of the foot-rule of every other carpenter.

Carpenters measure by feet and inches; machinists file iron by fractions of an inch—as $\frac{1}{32}$ inch, $\frac{1}{64}$ inch; shopkeepers sell cloth and ribbons by the yard; surveyors measure roads by the mile.

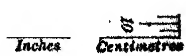


FIG. 46. American inches compared with French centimeters.

The Metric System.—In France there is a metal bar kept by the government as a standard. The distance between two particular lines on it is called a *metre* (or *meter*). A meter $= 39\frac{37}{100}$ inches; it is about three inches longer than a yard.

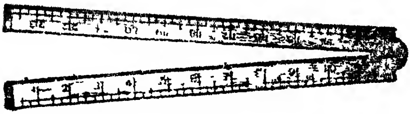


FIG. 47. A carpenter's two-foot rule. It is usually made so as to be only six inches long when folded up.

A *kilometer* is 1,000 meters — about $\frac{6}{10}$ of a mile.

A *decimeter* is $\frac{1}{10}$ of a meter — about four inches.

A *centimeter* is $\frac{1}{100}$ of a meter — about $\frac{4}{10}$ of an inch.

A *millimeter* is $\frac{1}{1000}$ of a meter — about $\frac{4}{100}$ of an inch.

A *gram* is the French measure of weight and it is equal to about $\frac{4}{100}$ of an ounce; a *kilogram* is about 2 pounds.

A *litre* is the French measure for liquids, etc., and it is about equal to our quart.

The French measures are used over nearly all of the continents of Europe and of South America, and the laws of the United

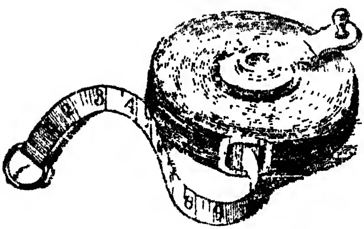


FIG. 48. A tape-measure. Short tapes a yard (3 feet; 36 inches) long are used by salesmen to measure cloth or ribbons. Longer tapes (50 or 100 feet long) are used by carpenters and masons. Tapes made of flexible steel are used by surveyors to measure land, lay out streets and so forth.

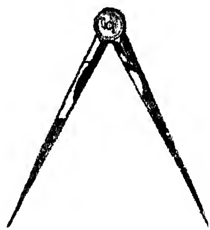


FIG. 49. Compasses or dividers. These are used by men who draw plans, by carpenters and machinists, to carry a measure made in one place over to another place; or else to find out how many inches long a piece of wood or iron must be to be of just the same length as a plan of it drawn in an office beforehand.

States allow our merchants to use them also; and that is the reason they are mentioned here.

Time.—The instant when the sun is highest in the sky—half way between sun-rise and sun-set—we call *noon*. Our watches are set so as to mark $12^h\ 0^m\ 0^s$ at the instant of noon, and regulated so as to mark $12^h\ 0^m\ 0^s$ again at the next noon. From Monday noon to Tuesday noon is a day = 24 hours. One hour = 60 minutes; and the minutes are marked on all watch-dials. One minute = 60 seconds; and the seconds are marked on most watch-dials.

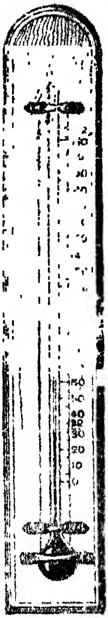
To keep account of the days we give them names (Monday, Tuesday, and so forth) because we find it convenient, just as it is convenient to name children (Tom, Agnes, Mary, Jack, and so forth). Monday begins at midnight of Sunday; Tuesday begins at midnight of Monday, and so on. Seven days make a week (the first day of the week is Sunday, the second Monday, and so on). The weeks have no names. It has not been found convenient to name weeks as days are named. But months are named for convenience (January, February, and so forth). Some months have 30 days, some 31 and one has 28. (Name them.)

A year has 12 months and common years are 365 days long. 365¼ days is the time required for the Earth to go once round the Sun. It is the period from one midsummer to the next one, from one Christmas to the next one. Every fourth year we call a leap year and it has 366 days (February has 29 days in a leap year). The number of days in four years is, then, 365 + 365 + 365 + 366 = 1461. One fourth of 1461 is 365¼. The years are numbered. The first year of the twentieth century began January 1, 1901. The next year was 1902 and so on. The count began with the year in which Christ was born (about 1900 years ago). He was born within the first century and the centuries are numbered. It is convenient to say that England was conquered by the Normans in the XI. century; that America was discovered by Columbus in the XV. century; that the Pilgrims came to America in the XVII. century: that our Revolutionary War was fought in the XVIII. century; and so on.

HEAT.

Thermometers.—A thermometer is made of a glass tube partly filled with quicksilver, but with no air in the tube. A scale of degrees is engraved alongside the tube. If you put the thermometer into melting ice (or freezing water) the quicksilver stands at 32° of the scale; "Freezing Point." If you put the bulb of the thermometer into your mouth the mercury will stand at about 98°. That is the temperature of your body. If you stand the thermometer in a kettle of boiling water[1] the mercury will rise to 212°.

[1] Do not put a cold thermometer suddenly into boiling water if you do not want to break it. Warm it at a fire beforehand.



FAHRENHEIT.

FIG. 50. A Thermometer with the quicksilver standing at 30°.

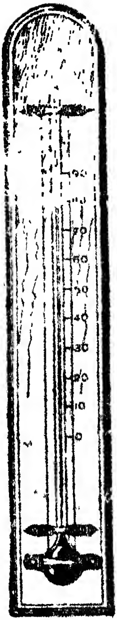


FIG. 51. A Centigrade Thermometer. The scale is divided into one hundred degrees. Such thermometers are used in European and South American countries.

Centigrade Thermometer. — The French and most other nations use a different scale for their thermometer from that used by the Americans and English. Our scale is called Fahrenheit's scale[1] from the German scientific man who invented it about 1714. Theirs is called Centigrade, because there are 100 degrees between the melting point of ice (0°) and the boiling point of water (100°). It is used everywhere by scientific men and in most countries of Europe and South America in commerce.

The "heat" of boiling water is the heat that it has got from the fire. Its "temperature" is 212°. The "heat" of your body is the heat you have got from the food you have eaten. The "temperature" of your body is 98°.

Melting Points; Boiling Points.—The melting point of ice is 32°, the boiling point of ice (or water) is 212°. The melting point of anything is the reading of the thermometer when that thing changes from a solid into a liquid; the boiling point is the reading of the thermometer when that thing changes from a liquid into a gas.

[1] Pronounced fa'ren-hīt.

The melting point of ice is 32°; it changes into liquid water.

The melting point of quicksilver is −38°; it changes from solid quicksilver into liquid at 38° below zero.

The melting point of solid sulphur is 240°; it becomes liquid.

The melting point of solid lead is 600°; it becomes liquid.

The melting point of solid iron is 2,200°; it becomes liquid.

The boiling point of water is 212°; in changes into steam.

The boiling point of alcohol is 172°; it changes into gas.

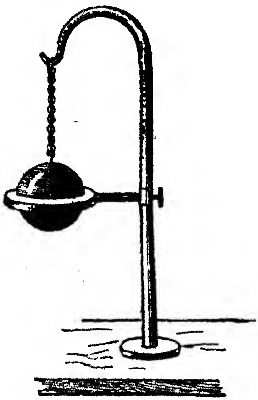


FIG. 52. An iron ball that just fits a ring when it is cold will be too large to slip through it when the ball is red hot. This is a proof that iron expands when heated. The ring remains of its old size. The ball is larger when it is hot. (An apparatus like that in the picture can be made by any ingenious boy.)

Hot Bodies Usually Expand.—The tire of a wagon wheel is larger when it is hot than when it is cold. The blacksmith tries a cold tire and finds that it is too small to fit the wheel. He heats the tire; it expands. He slips it over the wheel and lets it cool. It shrinks and fits tight. The quicksilver column in a thermometer becomes longer as the column gets hotter.

Nearly every solid thing is larger when hot than when cold. Very hot cannon balls are larger than the same balls when cold, as can be told by measuring them. Railway rails are longer when hot than when cold and you will notice that they are laid down with a little free space at the end of each rail to allow for expansion. Melted lead takes up more space than cold lead. But there is one important exception to this general rule. Melted ice (water, that is) takes up less space than cold ice. Water gets larger when it freezes, not smaller. This is the reason why our water pipes so often burst when the water freezes. The pipes are full of water at first; when the water freezes it expands and the pipes break.

Conduction of Heat.—Heat is conducted through bodies somewhat as if it were water flowing through pipes. Some bodies (things) let the heat flow fast. A silver spoon, for instance, dipped in boiling water will soon be hot all along its length. (Try it.) A piece of charcoal alongside of the silver will be very hot where it dips into the water, but will remain cool at its upper end. (Try it.)

Silver, iron, copper and other metals are good conductors of heat; charcoal, wood, wool, felt, fur, are poor conductors of heat. We make our winter clothes out of wool and fur because they do not conduct the heat of our bodies away to the cold air. A jacket made of copper would keep the wind away thoroughly, but it would be a very poor garment for cold weather. (Why?).

Work can be Turned into Heat.—If you rub two sticks together both sticks get warmer. Savages light fires by turning a stick of hard wood rapidly in a dent in a piece of soft wood. The hard wood is moved as if it were an auger, boring into the soft wood. By and by the soft wood begins to char and to burn. The movement that you give the stick is turned into heat. If you bore a hole in hard wood with a gimlet both wood and gimlet become warm. If you rub your hands together in cold weather you can warm them. In all these cases work of some sort has been turned into heat. If you place a copper cent on an anvil and pound it with a heavy hammer the coin becomes hot. (Try it.) The harder and faster you pound the hotter becomes the coin. A machine could be made to do the pounding so hard and so fast that the coin would become red hot. The work done by the hammer has somehow been taken up by the coin, and given out as heat.

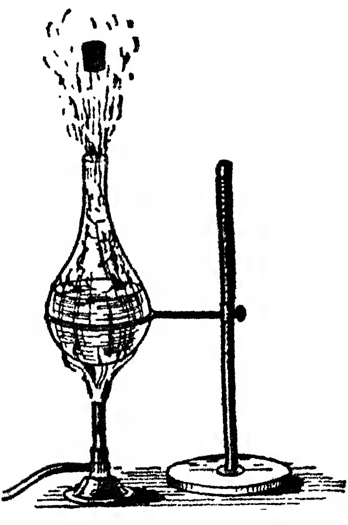


Fig. 53. Steam from heated water will drive out a tightly fitting cork.

Steam.—When water is boiled in a tea-kettle steam is formed and escapes through the spout and by lifting the lid. If the spout were securely stopped up and the lid soldered down the steam might burst the tea-kettle just as it sometimes bursts boilers. Steam can do work, then. In the steam engine it is made to do useful work.

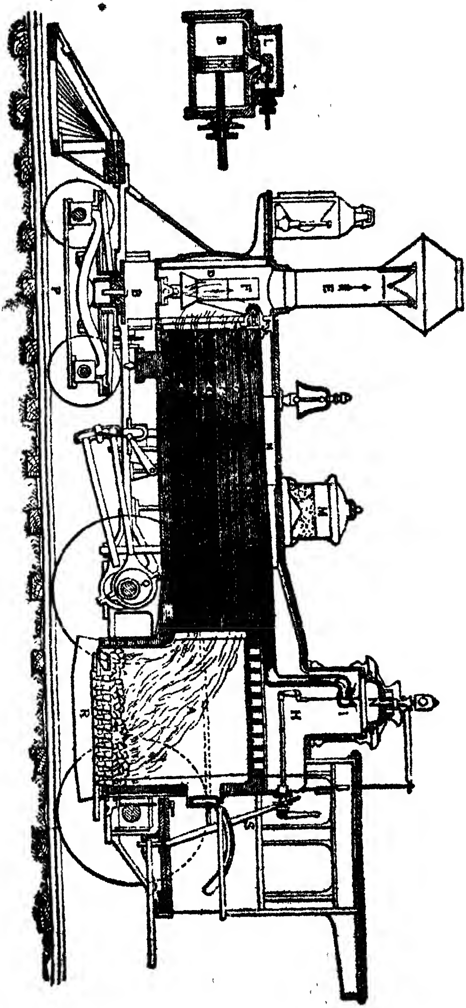


Fig. 54. A locomotive.

The Steam Engine.—The steam engine is a machine that turns heat (of the fire) back into work. The fire makes the wheels of the locomotive turn. You have often seen a locomotive. It is worth while to understand how it works.

A (Fig. 54) is the fire in the *fire-box*; the heat goes through tubes in the *boiler* (*G*) and turns the water round the tubes into steam. The steam is led by a pipe into the *steam-chest* (*H*) and from there it goes through another pipe to the *cylinder* (*B*) just above the front wheels of the locomotive. (There is a separate picture of the cylinder at the top of page 61.) Inside of the cylinder a *piston* (*K*) fits

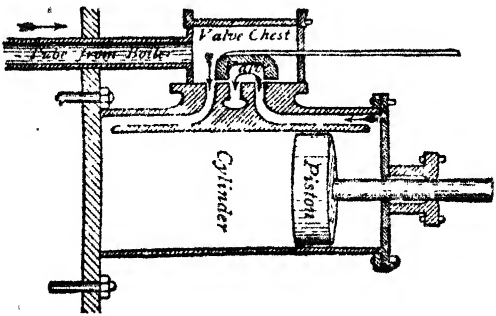


Fig. 55. Another picture of the cylinder of a steam-engine. The steam rushes from the boiler into the *valve-chest* and through the open way into the cylinder and pushes the piston to the right (in the picture). Then the steam is let into the cylinder by another way and pushes the piston to the left (in the picture). The piston-rod keeps moving to and fro. It is fastened to the driving-wheels by a crank, and the wheels keep moving round and round, and the locomotive keeps moving along, dragging the train after itself.

tightly and the *piston-rod* goes out of the cylinder and is fastened to the large *driving wheels* at the rear end of the locomotive. The machinery is so arranged that the steam is first let into the front end of the cylinder (*B*) and drives the piston backward, then the steam is let into the rear end of the cylinder and drives the piston forward. The piston keeps moving to and fro, and therefore the wheels keep turning round, and the locomotive keeps going.

The pupil should read this description carefully, pointing with a pin at the different parts of the engine as they are named.

LIGHT.

The Sun and Stars Shine by Light of Their Own.—The Sun and all the stars give out light of their own. The Moon has no light of its own but shines by reflecting the Sun's light to us. At times only part of the Moon's face is shined on by the Sun and only part of it, therefore, is seen by us. (See page 26 for an explanation of this.) A candle, an electric light, a fire-fly, a glowing coal, shines by its own light. It is *self-luminous*. Phosphorus is self-luminous, as you can prove by going into a dark closet and rubbing the head of a match gently with your hand. (Try it.) The head of the match contains a good deal of phosphorus,

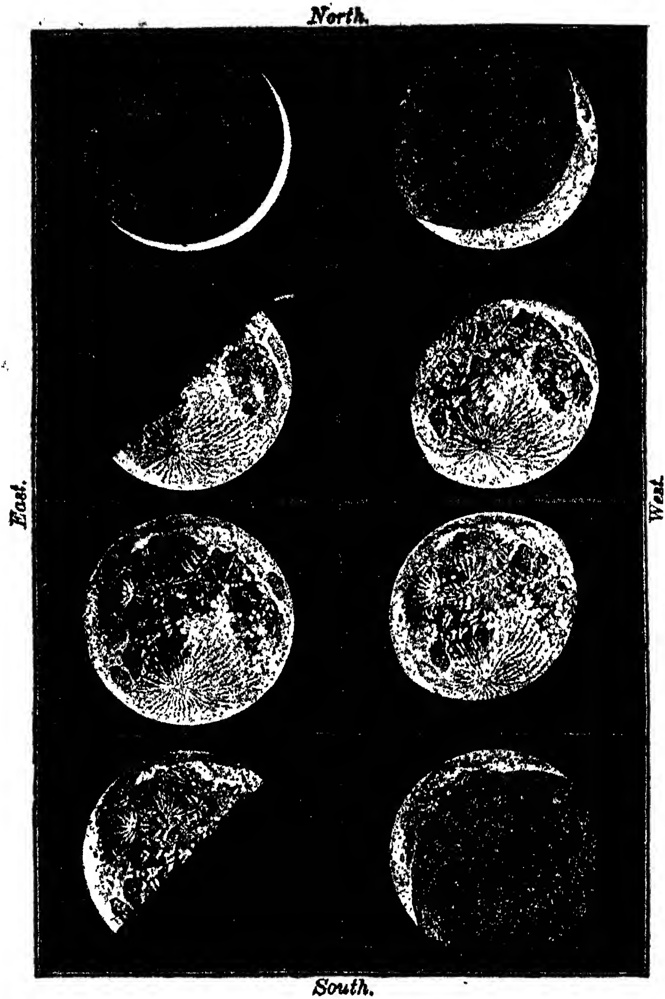


FIG. 56. The Moon as it appears to us at different times of the month.

(p. 64)

The upper pictures show the *New Moon*. The third picture shows the Moon half bright, and the others show how the Moon looks at other times. The Sun shines on half the Moon's globe—the half turned towards the Sun—and makes it bright. We look at the Moon and see half of its globe—the half turned towards us. Sometimes the whole of the part turned towards us is lighted, as in the fifth picture. Usually less than this is bright.

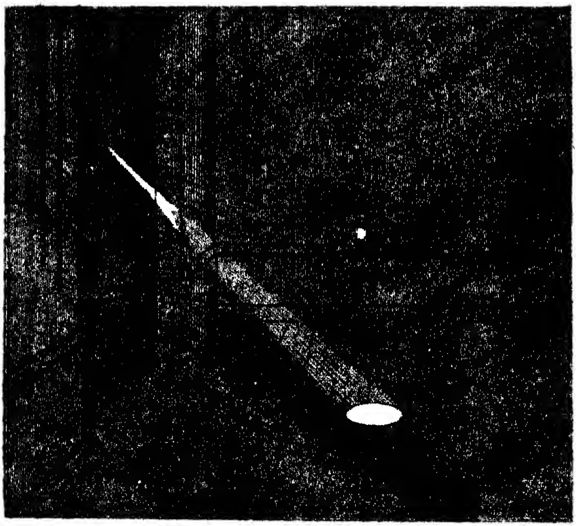


FIG. 57. The Sun shining into a darkened room through a small hole in the wall. The rays of the Sun travel in straight lines. If there is dust or smoke in the room it is easier to trace the course of each ray. Burn a newspaper, then. Notice that the Sun makes a spot on the floor which is an *image*—a picture—of the Sun.

In the daytime all sorts of things shine—a white-washed wall, the windows of a house, a piece of tin, a mirror, a diamond, and so forth. As soon as the Sun goes down they stop shining. They shone, then, by the sun's light. They were *luminous* (light-giving) but not *self*-luminous. Most things in the world are seen by the Sun's light which they reflect. The light comes to them from the distant Sun; they reflect it somewhat as a mirror reflects; and the reflected light enters your eye and you see them. When the Sun goes down you see them no more: unless, indeed, they are lighted by rays from a lamp. Daylight is the Sun's light reflected from and scattered by dust in the atmosphere, from clouds, the ground, buildings, streets, and so forth.

All Light-rays Travel in Straight Lines.- The Sun's rays travel in straight lines. You can prove this by making some room that faces the south very dark and by then letting in a ray of sunlight through a small hole.

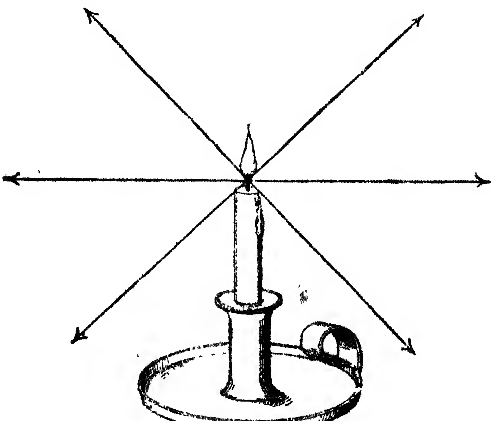


FIG. 58. Rays of light from a candle go in all direction.

Rays of Light go in All Directions.—An electric street lamp, for instance, shines towards the north, east, west, south. It shines upwards and downwards. Its rays of light must, then, go in *all* directions. If you put a candle in a darkened room, the whole of the room is lighted—the ceiling, the walls, the floor. Wherever you place your eye some ray from the candle will enter it. Wherever you are you can see the candle. This proves that the candle's rays go in all possible directions, up, down, sidewise. The Sun shines in every possible direction, too—towards the north, east, south, west.

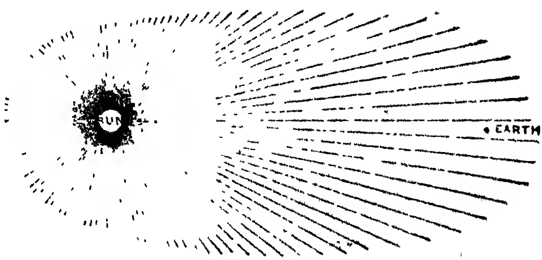


FIG. 59. The Sun sends out rays in *all* directions. The Earth receives only a small part of them.

Shadows.—When the Sun shines on any body (thing) it lights one half of it. The half turned towards the Sun is lighted. The half turned away from the Sun is not lighted. Beyond the body that is shined upon there is the shadow. The shadow of a thing is the space beyond it from which it keeps the light away. Your shadow, properly speaking, is not the flat distorted picture on the ground, but all the space back of you, from which your body keeps the light away.

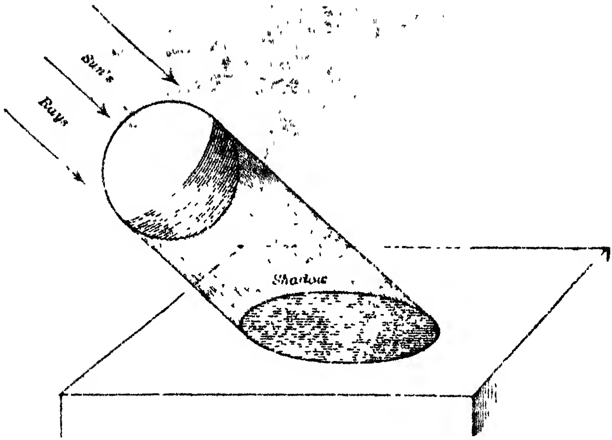


FIG. 60. The Sun shines on a ball and lights one-half of it; the other half is not lighted. All the space back of the ball which is not lighted is its shadow, though we often speak of the dark oval, where the shadow meets the table as "the shadow of the ball."

To the side of the Earth lighted by the Sun it is daytime; to the other side of the Earth, it is night; beyond the Earth its shadow extends for thousands of miles. In the same way, the Sun lights one half of the Moon (the half turned towards the Sun); the other half of the Moon is dark; and beyond the Moon its shadow stretches out for thousands of miles.

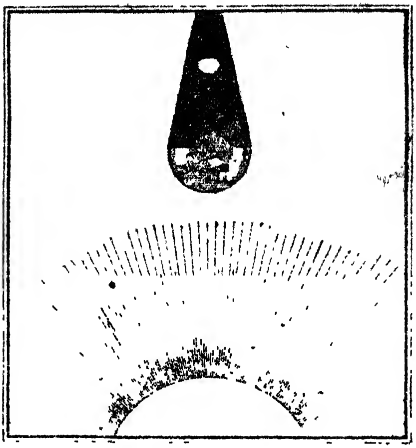


FIG. 61 The Sun shining on the Earth (or the Moon) lights one-half of it. Beyond is the unlighted shadow from which the Sun's rays are cut off.

Place a candle on a table in the middle of a dark room and hold a pencil near the candle. Hold a sheet of white paper a foot beyond the pencil and let the shadow of the pencil fall on the paper. Keep the pencil in the same place and move the paper two feet away; then three feet; and so forth. Now move the pencil further away from the candle and try the same experiments again. Put two candles close together and try the same experiments. Each time look for the *umbra* and for the *penumbra* of the shadow. The *umbra* is the darkest portion of any shadow; the *penumbra* is the rest of the same shadow. With only one candle make the shadow of a ball—of a book—of a card. Hold the card edgewise towards the light—flatwise—inclined. Cut a circle out of a card and try to make its shadow round—oval—a straight line. (See Figs. 29, 30.)

Shadow of an Obelisk.—When the Sun is high in the heavens the shadow of an obelisk on the ground will be short as in Fig. 62. When the Sun is lower, the shadow on the ground will be longer, as in Fig. 63. The height of the Sun in the heavens can be calculated by simply measuring the length of the shadow on the ground— by measuring *LM*. The ancient astronomers of Egypt determined the Sun's height in this way.

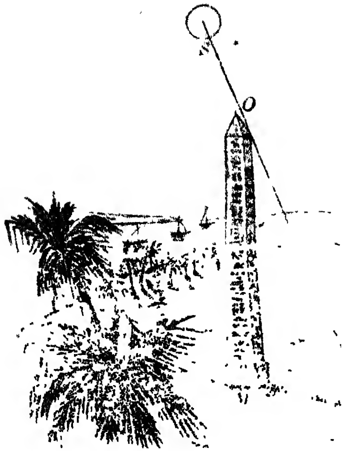


Fig. 62. The shadow of an obelisk when the Sun is high in the heavens.

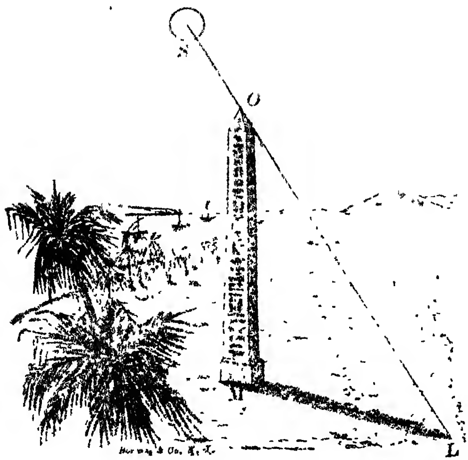


Fig. 63. The shadow of the same obelisk when the Sun is not so high in the heavens.

The Sun-Dial.—The ancients used to measure the time of day by the movement of the shadow on a sun-dial.

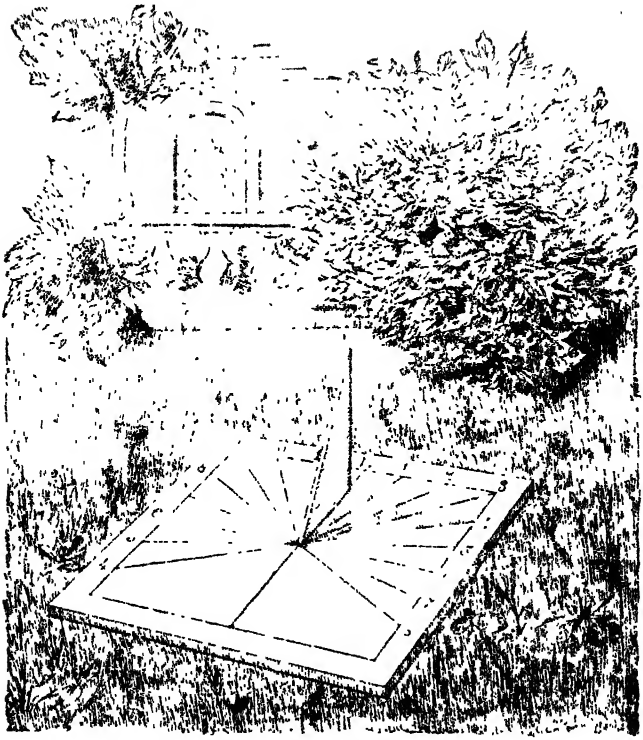


FIG. 64. A Sun-dial. The line through the figure 12 in the picture lies exactly north and south, with 12 at its north end. As the Sun moves the shadow moves. The picture was taken at four o'clock in the afternoon. How do you know it was not taken at four o'clock in the morning?

Reflection of Light by a Mirror.

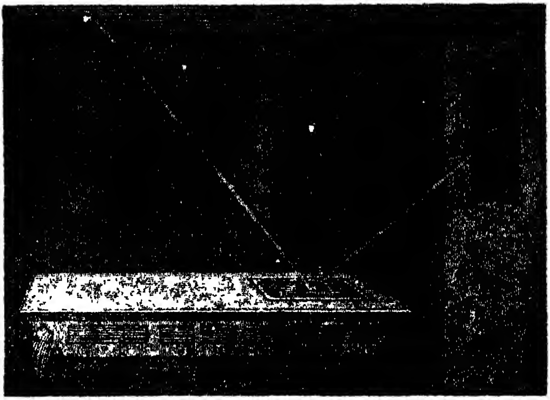


FIG. 65. A beam, or ray, of light is reflected by a mirror, as you know very well; and as can be proved by the experiment shown in the picture.

Let a ray of light into a darkened room through a very small hole and move a mirror till the ray strikes it. The ray will be reflected so that it strikes the ceiling. (Try it.) If you set up a vertical ruler at the point where the ray strikes the mirror the *angle ABD* will *always* be equal to the *angle DBC.*

The teacher should cut a piece of stiff paper so that two of its edges make an angle equal to *ABD*; and by turning the paper prove that it is equal to the angle *DBC*.

Reflecting Telescopes are made by using curved mirrors to collect the rays of light and to direct them to the eye of the observer who uses a magnifying eyepiece.

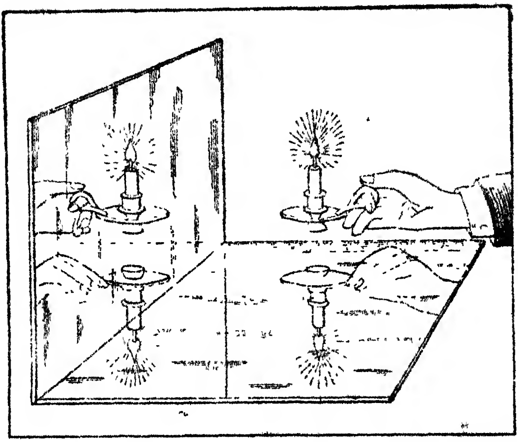
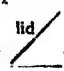


FIG. 66. *Kaleidoscope.*—Images of a candle made by two mirrors at right angles to each other. There are three images. (Try it.)

If two mirrors *a* and *b* are placed so that they make an angle of 60° with each other like this 

the reflections will be six-sided. Anyone can try this experiment by I. folding back the lid of an upright piano till the lid and the top make an angle like this 

. The polished lid and top are mirrors. II. by putting a shawl over the lid so as to make a dark box with the two ends open. III. by placing his eye at one end of the triangular box while a friend moves some bright object like a skein of worsted, a bunch of keys and so forth to and fro at the other end. (Try it.)

Refraction of Light. A ray of light in the air moves in a straight line. When it moves first in air and then in water the ray is bent just where it enters the water. Take a tumbler half full of water and put a spoon in it. Hold it in front of you at arm's length so that the top of the water is on a level with your eye. (Try it.) The spoon will look as if it were bent out of shape—as if it were broken. The water breaks—refracts—the light.

Refraction of Light by a Prism:

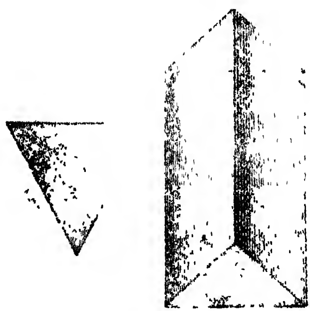


FIG. 67. A triangular prism of glass. Look at it endwise and you see a triangle as in the left-hand picture. The glass pendants to chandeliers are often prisms.

When a ray of light passes through a prism of glass it is also bent out of its course.

Refraction of Light by a Lens.—A *lens* is a piece of glass with curved sides (a burning glass, for instance) which is used to bend rays of light from their first course into a new one.

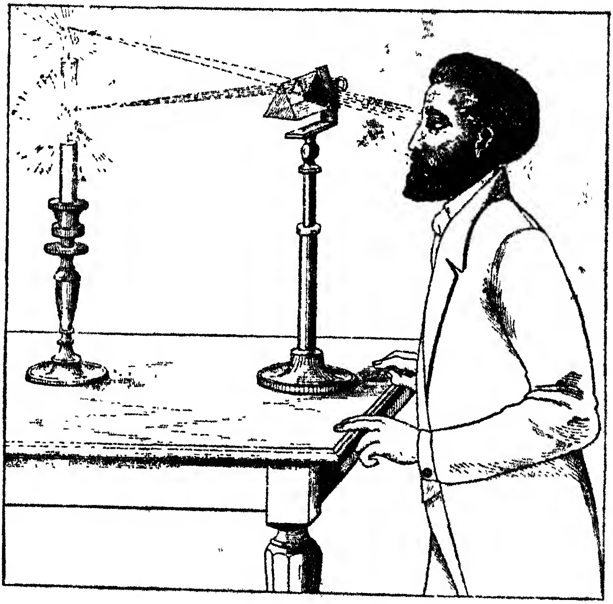


FIG. 68. The light from the candle strikes the prism and is bent down so that the man sees the candle not where it is, but raised in the air. If you have a prism, try it.

Microscope.—If you take a burning glass like that in Fig. 70 and use it to look at this page of your book you will find that it magnifies the letters.

(Try it.) A microscope is a lens or a set of lenses used to make small things appear larger.

Microscopes are used by geologists to study the structure of rocks; by physicians to study the bacteria that produce diseases, and so forth.

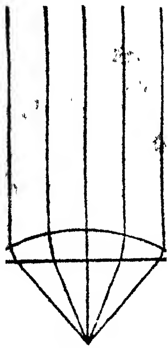


FIG. 69. Hold a burning glass in the sunlight and it will bend the rays of the Sun so that all that fall upon it meet in one point—which is called the *focus*. A burning glass collects the Sun's rays into a small spot of light. All the rays that fall on all the surface of the lens are brought to a single spot.

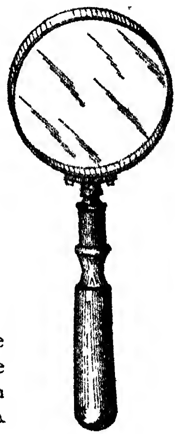


FIG. 70. A burning glass.

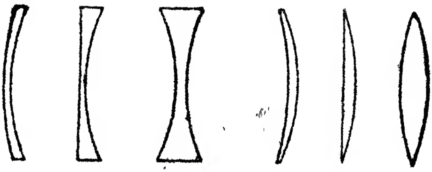


FIG. 71. Glass lenses of different shapes. *Spectacles* are lenses of these kinds. The different kinds are used for eyes with different sorts of troubles. Near-sighted eyes need concave glasses, far-sighted need convex glasses.

Telescope.—A telescope is an apparatus used to make far off things seem near (a spy-glass is a small telescope; so is an opera-glass). It is usually made of two, or more, glass lenses. The first lens collects the rays from the distant object at its focus and forms a little picture of the object there. The second lens magnifies the little picture. The two lenses together form a telescope.

In an opera glass, one lens is at the large end; the other (or others) near the small end. It magnifies from 3 to 8 times. It makes things seem 3 to 8 times nearer than they really are.

A large telescope such as astronomers use to look at the stars can be made to magnify about a thousand times. It makes the Moon seem about a thousand times nearer than it really is.

The Solar Spectrum:

You can hold a prism in the sunlight so as to get a band of colored light. (Try it.) There will be seven colors, Violet, Indigo, Blue, Green, Yellow, Orange, Red -VIBGYOR (remember this word and it will recall the order in which the colors come. It is the order of the colors in the rainbow). The prism does two things to the sunlight that falls on it: I. It bends the light into a new course; II. It separates the light into seven colors. Sunlight is made up of seven colors and no more. When they are all together they make what we call *white* light, that is, sunlight. It is just as if every beam of sunlight were made up of seven strands of silk thread—*vibgyor*. When they are all in one bundle they look white. Separate the bundle into parts, and you have seven separate colors—violet, indigo, blue, green, yellow, orange, red. A few experiments with a prism will prove this. Looking at the rainbow proves it. The white sunlight going through the drops of rain (which act somewhat as if they were prisms) is separated into seven colors.

Velocity of Light.--Light travels from place to place at the rate of 186,000 miles in one second of time—almost instantaneously: almost, but not quite. It comes to us from the Moon in less than two seconds, but it takes eight minutes to come from the Sun. That is, a ray of light that left the Sun eight minutes ago arrived at the Earth this very instant. A ray of light just leaving the Sun now - this instant--will not arrive for eight minutes. Eight minutes are required to make the journey of 93,000,000 miles. Light goes from any one place on the Earth to any other place practically instantaneously. You see an electric street lamp at practically the very instant when it is lighted. You see the flash of a gun the instant it is fired, though you do not hear the sound for some seconds.

SOUND.

Sound-waves.—When a church-bell is struck by a hammer a sound is heard. No matter where you are—north, south, east, west of the bell--you hear it. Close to the bell the sound is loud; two miles away the sound is faint. Anywhere within two miles you hear it. This proves that waves of sound travel outwards from the bell, in every direction, somewhat as waves of water travel outwards from a stone thrown into a pond. The waves are more marked where the stone struck the water; less marked as they go outward. (Try it.)

Finally they die away somewhat as the sound of the bell dies away.

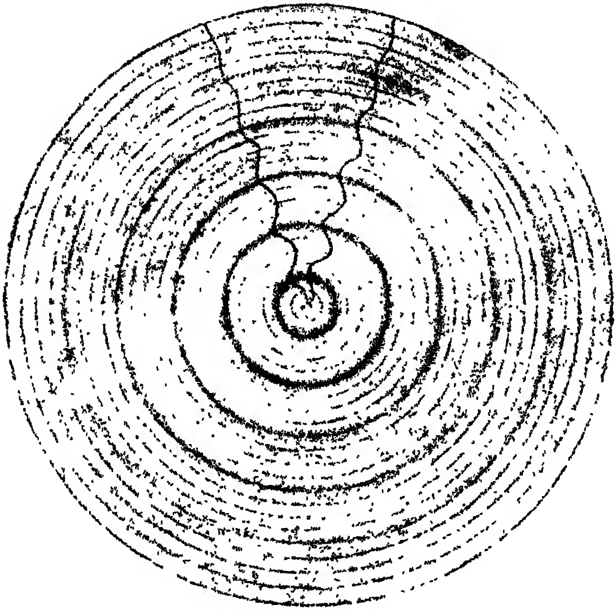


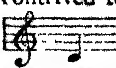
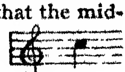
FIG. 72. Waves of water made by a stone thrown into the center of a pool look like the picture. The two wavy lines would not be seen, of course. They are drawn to show the heights of the waves at different distances from the center. The further you go from the center the smaller is the wave.

Sound is Caused by a Vibration.--The hammer strikes the bell and the whole bell trembles—vibrates. If you touch the bell with your finger the vibration can be felt. If you strike a thin tumbler with a spoon there is a sound. If you hold your finger lightly against the glass you can feel it tremble—vibrate. (Try it.) So long as the trembling goes on the sound is heard. Stop the trembling by clasping your fingers round the glass and the sound will stop. (Try it.) To have a sound you must first have vibration of some sort. A vibration is a quick trembling to and fro, like that of a bell when it is struck.

FIG. 73. A wine glass filled with water vibrates when a fiddle bow is drawn across its edge. Touch the glass lightly with your finger and notice that at four places there are no waves. (Try it.)

Musical Instruments.—A drum makes a sound because the parchment drum-head vibrates when it is struck. The air vibrating regularly in an organ-pipe makes a sound. The string of a violin vibrates when the bow is drawn across it, just as the string of a piano vibrates when the hammer strikes it. You can feel the vibrations of the piano strings by putting your finger lightly against them. (Try it.)

The vibrations of all musical instruments are regular—rhythmical—and the sounds are pleasant. Such sounds are called musical. Irregular vibrations, such as are made by beating on a fence with a stick, are unpleasant—we call them noises.

A way has been contrived to count the number of vibrations of the strings of a piano. It is found that the middle C of the piano  is made by a string vibrating 256 times in a second; the C next above 

is made by a string that vibrates 512 times in a second. The shorter the string the more vibrations it makes in a second. The shortest strings in a piano, the ones that give the highest notes, make about 4,000 vibrations in one second; the longest strings, that give the lowest notes, make about 32.

The sounding-board of a piano also vibrates when the string is struck and makes the sound louder; and all the air inside of a fiddle vibrates when the string is plucked. When you are at a concert recollect that all the air inside the concert-hall is set into vibration every time a note is played on the violin. Each stroke of the fiddle-bow sets tons of air into motion.

Singing.—You have in your throat two cords, muscles, called the vocal cords. By making them act you can change the quickness of the vibrations of the air that passes through your throat as you sing. Very deep bass sounds (men's voices) are made by air vibrating about 200 times a second; the very highest notes of a woman's voice are made by air vibrating about 2,000 times in a second. Learning to sing is mainly learning to control the vocal cords.

Sound Travels Through the Air.—Open the window of a room and send a boy to beat on the fence with a stick. You hear the sound which is brought to you by the air. The air cannot go through the window when it is closed. Close it then; and you cannot hear the sound, though you can still see the stick striking the fence.

6

If the fence is very near, and if the boy strikes very hard sometimes you can hear the sound even when the window is shut. That is because the air outside of the window makes the window-glass vibrate, and because the window-glass, in turn, sets the air in the room into vibration. Sounds usually come to us from the sounding body (thing) by vibrations in the air.

But sound travels through solids too. If you hold a watch close against a long plank a boy at the other end of the plank can hear the ticking much plainer than if you hold the watch a foot away from the plank. (Try it.) The ticks of the watch travel through the plank in the first experiment; through the air in the second. If a railroad train is far away, you can hear it better by laying your ear close to the rails than you can by standing up and listening.

Velocity of Sound.—Light travels almost instantaneously trom place to place. You see the flash of a distant gun the moment it is fired. But the sound does not come at once. If the gun is 1,100 feet away from you the sound comes one second of time after the flash. If the gun is 2,200 feet away the sound comes two seconds after the flash. Sound travels 1,100 feet (about a fifth of a mile) in one second. It travels a mile in a little less than five seconds.

Any two country boys who own a watch and a gun and who can get a mile apart can prove this. City boys are not allowed to fire guns in the streets but they can recollect that sound travels a distance of about 500 of their steps in each and every second of time.

ELECTRICITY.

Experiments.—Before beginning the experiments you should get

A piece of sealing wax about 4 inches long.

A glass tube or a glass rod about 4 inches long.

A little piece of elder pith with a silk thread run through it so that it can be hung to a long nail in the wall, or to the end of a stick projecting from a shelf (put a heavy book on one end of the stick to keep it steady),

A *little* ball of sealing wax fastened to a silk thread.

A *little* glass bead fastened to a silk thread.

A pound of resin; have it melted and poured into a shallow wooden box to cool. (See Fig. 75.)

A piece of fur—a cat-skin will do very well.

Electricity by Friction.—Now try these experiments one by one:

I. Strew some small bits of paper on the table and hold the sealing-wax, then the glass, near them. Nothing happens.

II. Rub the sealing-wax smartly on the fur or on your sleeve, and then hold it near the bits of paper. It attracts the paper. The little bits of pieces fly to the wax and stick to it.

III. Rub the glass rod smartly on your sleeve and hold it near the bits of paper. It attracts the paper.

Whenever a piece of wax or glass is rubbed it gets a new power. It will attract light bodies such as bits of paper. Before it was rubbed it did not have the power. It is the rubbing—the friction that, somehow, gives the new power to the wax or glass.

The ancients, thousands of years ago, knew that if amber was rubbed it would attract light bodies, such as bits of chopped straw. The Greek name for amber is *Electron*, and from that word we get our name of electricity.

Electricity is the something that gives a piece of glass that has been rubbed the power to attract pieces of paper.

When sealing wax is rubbed you get electricity of one sort; when glass is rubbed you get electricity of another sort, as the following experiments will show:

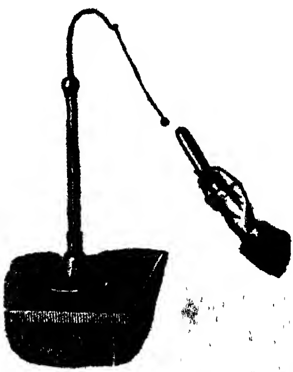


FIG. 74. A pith-ball hung by a silk string is repelled by an electrified stick of sealing-wax, or glass.

IV. Fasten a little pith ball so that it can swing freely. Hold a piece of sealing-wax near it. Nothing happens if the wax has not been rubbed. Hold a piece of glass near it. Nothing happens if the glass has not been rubbed.

V. Rub the wax and then hold it near the pith-ball. The ball is first attracted and then quickly repelled. The wax repels the ball.

VI. Rub the glass rod and quickly bring it near to the pith-ball. The ball was *repelled* by the rubbed sealing-wax, but it is now *attracted* by the rubbed glass. Wax-electricity seems to be different from glass-electricity.[1] When one repels the pith ball the other attracts it.

VII. Rub the glass first, and it will repel the pith ball; then quickly rub the wax and it will attract the ball. Wax-electricity is certainly different from glass-electricity. You have proved it to be different.

VIII. Rub the little sealing-wax ball with a piece of fur; rub the stick of sealing-wax and bring them close together; they repel each other. If now the glass rod be quickly rubbed it will attract the wax ball.

IX. Rub the glass bead and bring the rubbed glass rod near. They repel each other. The rubbed stick of wax will attract the ball.

All these experiments taken together prove that:

When bodies are charged with *like* electricities, they repel each other [wax repels wax, glass repels glass].

When bodies are charged with *unlike* electricities, they attract each other [wax attracts glass, glass attracts wax].

X. Take the wooden box filled with melted resin and beat or rub it with a piece of fur. Now put

[1] The scientific names are resinous electricity and vitreous electricity: sealing-wax is made of resin.

your knuckle close to the resin and you will feel a little electric shock. Some of the electricity in the

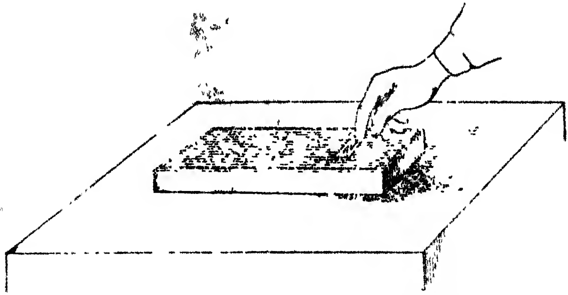


FIG. 75. Taking a spark from a box of resin which has been electrified by beating it with a piece of fur.

resin has gone into your body. If this is done in the dark you can see a little spark pass; and whenever the spark passes there is a little crackling noise. The spark is just the same thing as *lightning;* the little noise is thunder. Your knuckle was struck by lightning.

If you break a piece of sugar while you are in the dark you will see a faint light which is caused by electricity. Breaking the sugar is a kind of rubbing of one surface on another. If you rub the fur of a cat with your hand you can electrify the cat and can take sparks from her back or from her nose (much to her surprise!) Rub a dry lamp-chimney with a woolen cloth and you can take sparks from it with your knuckle. In cold dry weather you can scuffle your shoes over the carpet and electrify yourself—so that you can light the gas by a spark between your knuckle and the metal gas-fixture. (Remember these things and try them all when the weather is cool and dry.) Notice that in such weather a rubber comb passed through your hair will attract the hairs and make them rise up.

FIG. 76. Benjamin Franklin bringing lightning from the clouds, 1752.

Until the time of Benjamin Franklin (1752) little more was known of electricity than what you have just learned. Electricity could be made by rubbing wax or glass; and there was lightning during a storm. Franklin electrified a kite by sending it up into a thunder-storm, and from a key tied to the kite-string he got sparks[1]; and he proved that the

[1] You must not try this experiment. It is dangerous, and you might be killed, as men have been, in trying it.

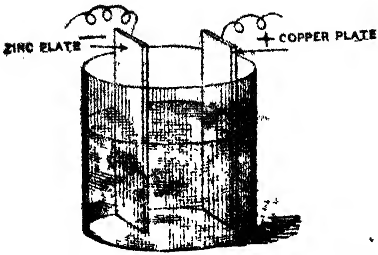


FIG. 77. One cell of an electric battery. The glass jar contains two plates, one of copper, the other of zinc, and a liquid, which is diluted sulphuric acid. A wire is fastened to each plate. The larger the plates the more electricity flows when the two wires are joined.

electricity in the clouds was the same kind of thing as the electricity that he could make, any-time, by experiments.

Electricity from Batteries. — Now-a-days electricity is used for sending messages by telegraph; and it is used to light lamps, to drive street cars, automobiles, elevators, etc. The electricity for telegraphs is obtained from batteries; for lighting and power from dynamos.

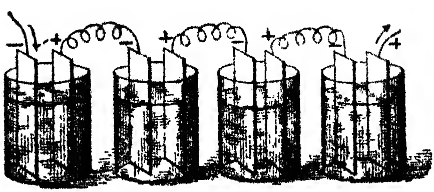


FIG. 78. Several cells of a battery joined together (the zinc plate of one cell to the copper plate of the next one). A strong electric current flows through the wires when they are joined, no matter if the wire is short or long. If the wire extends from Boston to New York a current will flow and if we can make the current work telegraph sounders in the two cities we can telegraph messages.

You can prove that a current of electricity is flowing in a battery by putting one wire above your tongue, and the other below it (both touching the tongue). When you do this you will feel a little current every time you move the wires slightly. A current of electricity flows from the copper slip through the wire to your tongue, through your tongue and back to the zinc slip. The current runs round a circle of wire and such a circle of wire is called an *electric circuit.*

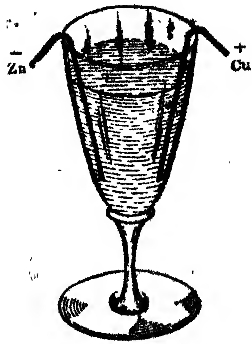


FIG. 79. A home-made electric battery. The glass goblet is filled with weak sulphuric acid and contains two slips of metal, one of Zinc (Zn), the other of Copper (Cu). To use it two pieces of flexible copper wire must be soldered to the two pieces of metal.

The cell that you make is not as strong or as convenient as one that you can buy, and it is worth while to buy what is called a cell of "dry battery,"[1] which is handy and clean to use.

[1] Buy for the school from the Western Electric Company, New York City, its Electric Bell outfit (complete) No. 9429, comprising a bell, one cell of Phenix Dry Battery, one bronze push-button, 75 feet of No. 18 annunciator wire and staples, for $2.75.

Electric Bells:

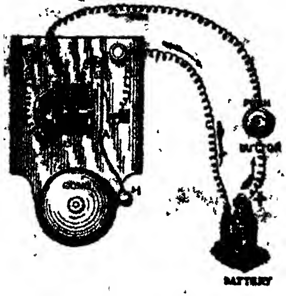


FIG. 80. An electric bell outfit complete—push-button (at the right), one cell of battery, bell and wire.

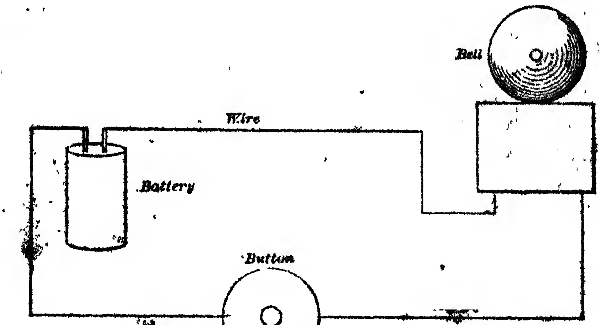


FIG. 81. Plan of the circuit for an electric bell. Touch the push-button and the bell will ring. Touching the push-button connects the two ends of the wire, previously unconnected. When the wire is all in one piece the electricity flows from the battery into the electro-magnet of the bell and makes the bell ring. If the battery were strong enough you could stretch the wires from New York to Boston and make a bell in Boston ring when a button in New York was pushed.

The Electric Telegraph.—Signals can be sent over a long distance by using strong batteries of many cells. Suppose we have a "sounder" in Boston, and a key and battery in New York, and connect all three by telegraph wire strung on posts.

FIG. 82. A telegraph key.

Whenever the key in New York is pressed a current of electricity from the battery runs along the wire and into the coils of the sounder in Boston. The sounder becomes a magnet and pulls down the bar above it with a click. Let go of the key in New York and the sounder-magnet lets go of the bar. We can thus make clicks that can be heard in Boston by touching a key in New York. The current of electricity does the work.

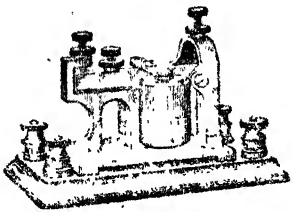


FIG. 83. A Sounder. It is an electromagnet (see p. 99) that is, it is a magnet whenever a current of electricity runs through its coils—whenever a key in the circuit is pressed; and not a magnet when no current is flowing. In the picture one of the coils is shown—a vertical black cylinder.

The Telegraph Alphabet.—An alphabet has been invented to use in sending telegraphic messages. The shortest touch of the key makes a short click which is called a *dot* . ; a longer touch makes a *dash* — .

To send A make a dot and a dash, . —;
" " B " a dash and three dots, — ... ;
" " E " a dot, .;
" " M " two dashes, — —.

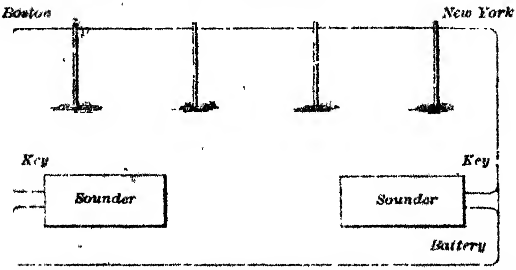


FIG. 84. Plan of a telegraph line between Boston and New York.

and so on for the rest of the letters. In this way any word can be spelled out to the ear in Boston by touches of a key in New York. A key (on the same circuit of wire) in Boston when touched will spell out words to the ear in New York. It is in this way that telegraph messages are now sent.

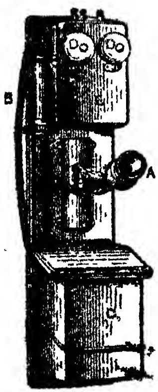


FIG. 85. Telephone. Each person who speaks has an instrument like this.

The Telephone.—The telephone is a kind of telegraph. It sends the vibrations of your voice instead of sending the clicks of the telegraph key, and this is done as follows:

I. You call the person you wish to speak to (or the central office) by ringing an electric bell (D).

II. You speak into your "transmitter" (A). This is a box containing a very thin disk of metal. When you speak the vibrations of your voice make this disk vibrate and the vibrations of the disk travel along the wires and reach the telephone which your friend is holding to his ear. In his telephone (and in yours (B) too) there is a little metal disk which vibrates just as your voice vibrates. The air in his telephone vibrates, then, just as your voice did; and it makes the same sounds that you made. It repeats your very words, even your whispers.

The Dynamo.—A dynamo-electric machine is a set of magnets made to revolve rapidly by a steam engine. When they revolve they create a current of electricity. Wires led from the dynamo carry the current wherever you wish. You can use the current to light lamps, or to run electric cars, or to drive any machine you choose. The more powerful your steam engine, the stronger current you can get and the more work you can do. It is the steam engine that does the work, after all.

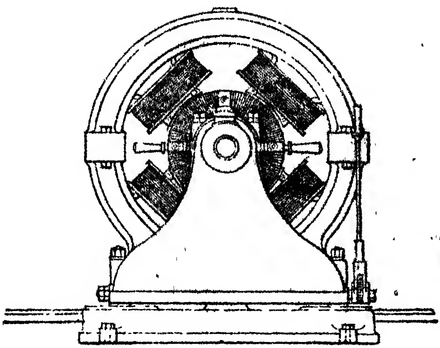


FIG. 86. A Dynamo.

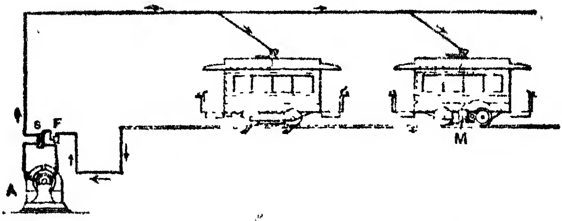


FIG. 87. An Electric Railway. The Dynamo (*A*) in the power-house sends a current of electricity along the wire. Each car takes the electricity it needs by the trolley and motors underneath the floor of the car drive the wheels

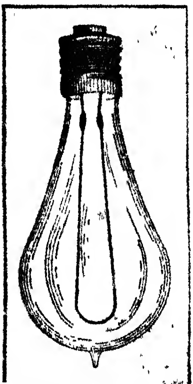


FIG. 88. An electric lamp; a glow-lamp: such as is used in houses. A current of electricity from a dynamo heats a little strip of bamboo white-hot, and the glowing of this strip gives the light.

The dynamo simply changes the energy of the steam engine into electricity and the wires carry the electricity to the places where you wish to use it.

The Electric Railway. — A dynamo driven by a steam-engine in a power-house (so-called) is used to send a current of electricity along an overhead wire, and the electricity is led from this wire by a little wheel (a *trolley*) to electric motors underneath the car. These motors turn the car-wheels round and make the car move along the track.

Electric Lighting.—A current of electricity is sent out from a power-house by a dynamo driven by a steam-engine. The current is led along wires to light the street lamps (arc lamps, they are called) in cities; and into houses to light the glow-lamps (incandescent lamps, they are sometimes called).

MAGNETISM.

Natural Magnets.—In Magnesia, a district of Greece, the ancients found a kind of iron ore that attracts little pieces of iron filings, tacks, etc., when they are brought near to it. The name "magnet" comes from the name of the place—"Magnesia." Natural magnets are found in many other parts of the world. To try the experiments described in this book it will be best to buy from any toy-shop one of the manufactured magnets shown in the pictures.

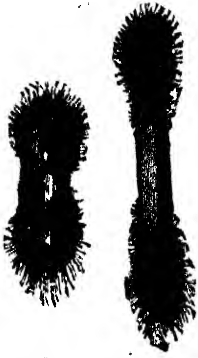


FIG. 89. A bar magnet dipped in iron filings. It is shaped like a bar. The ends of a magnet are called its poles.

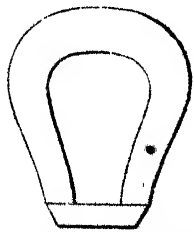


FIG. 90. A horse-shoe magnet: it is shaped like a horse-shoe. The piece of steel across the ends is called the *keeper*, or the *armature*.

Experiments.—Spread two or three needles on a table and pick them up with the magnet. (Try it.) Try to pick up some brass pins. If you make a little pile of bits of iron wire, steel needles, copper wire, brass wire, lead, sand, coal-dust, and so forth the magnet will pick out the iron and steel and nothing else. Whatever the magnet picks up *is* iron or steel. There is a machine made which sorts small pieces of iron out of a mass of crushed rock by a large magnet. If they were not picked out in this way you could not get them at all. Surgeons use magnets to take needles, etc., out of wounds. The mariner's compass is nothing but a magnet (page 99).

Magnetism.—A magnet, then, is something different from a piece of iron of the same shape. There is some force in the magnet that reaches out and attracts iron; somewhat as the forec of gravity (see p. 46) in the Earth reaches out and attracts heavy bodies (things). Notice that it is the *ends* of a magnet that attract. The middle parts scarcely attract at all. (Try it.)

Take a pane of glass and lay it on two piles of books, one at each end. Now lay a needle on the glass and move the magnet underneath. You will see that the magnet acts through the glass (try it); and it will act through paper or copper or cloth—through anything, in fact.

Artificial Magnets.—Take a fresh needle from the case and see if it will pick up little bits of iron. It will not. Now lay the needle down and rub it with the magnet, lengthwise, from the center towards the point for a minute. Then rub the needle with the magnet from the center towards the eye-end for another minute. The needle will now pick up iron filings. (Try it.) It has become a magnet. You can make magnets in this way. You can magnetize the blade of your pen-knife, if you like. The first artificial magnets were made from natural magnets. Now-a-days we make one artificial magnet from others, or by electricity as you shall hear later.

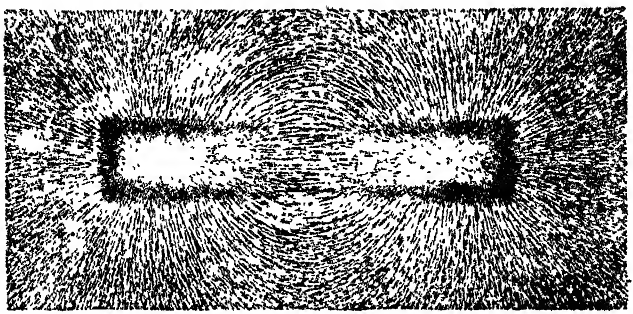


FIG. 91. A bar magnet was laid on a pane of glass and fine iron filings were spread all over the glass. The magnet attracted the bits of iron. After a while the magnet was lifted up and the picture was taken. Notice that the ends (poles) of the magnet attracted the most filings and that the middle attracted the fewest; all over the glass the filings are arranged in curves. You can try this experiment yourself. (Tap the edge of the glass gently with your finger nail to keep the filings from sticking to the glass.)

Experiments.—Take a fresh needle, lay it down, and magnetize it by moving the magnet from the eye-end towards the point. (Rub it only in this direction.) Magnetize a second needle in exactly the same way. Now you have two small magnets, just alike. Either of them will pick up iron filings. (Try it.) Tie a thread round the middle of one of them and hang it from a long nail in the wall, or from a gas bracket, so that it is horizontal and can swing freely. Let it come to rest.

Now take the second needle (call it No. 2 for short) and try these experiments and see what happens.

Touch the eye-end of No. 1 with the point end of No. 2; they attract.

Touch the point-end of No. 1 with the eye-end of No 2, they attract.

Touch the point-end of No 1 with the point-end of No. 2; they repel.

Touch the eye-end of No. 1 with the eye-end of No 2; they repel.

These magnets are just alike; the eye-end poles (ends) of each are alike, the point-end poles (ends) of each are alike. They were made in the same way and this must be true. But the experiments have shown that the eye-end poles are *not* like the point-end poles, and the experiments have also shown that *like* poles of two magnets repel each other; *unlike* poles of two magnets attract each other.

You must try these experiments over and over till you thoroughly understand them.—It is much easier to understand the experiments than to understand a description of them.

If any sewing needle is laid gently on the surface of water the needle will float. (Try it.)

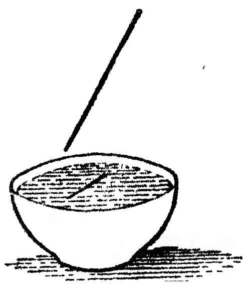


FIG. 92. A magnetized sewing-needle floating on a bowl of water.

If a magnetized needle is laid on water it will turn till it points to the north. It is a compass. (Try it.)

If you take another magnet and bring it near to the floating compass-needle you can easily prove that *like* poles of two magnets repel, *unlike* poles attract each other. (Try it.)

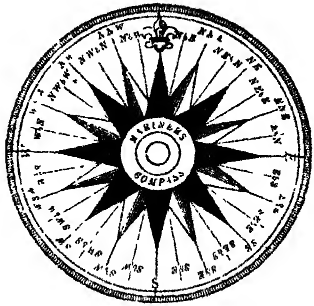


FIG. 93. The Mariner's Compass. The needle always points to the north, and therefore sailors can steer by it.

The Mariner's Compass.—If a magnet is suspended by a string (or balanced on a sharp point) or floated on water, so that it can swing freely, it will point to the north. The Chinese knew this centuries ago and used compasses to steer their ships by. Their invention was brought to Europe and has been used by our sailors since A.D. 1302.

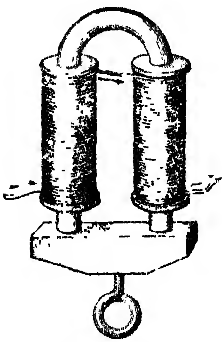


FIG. 94. An electro-magnet. It is a piece of iron wrapped with wire. While a current of electricity is flowing through the wire it is a magnet: the instant the current stops flowing it is a magnet no longer.

Columbus (1492) steered west from Spain by the compass and discovered America. If you have a compass see what will happen when you bring a magnet near to one of its ends. (Try it.)

Electro-Magnets.—You know that a current of electricity from an electric battery flows along a telegraph wire so that messages are sent from Boston to New York. Suppose you took a piece of soft iron and bent it into the shape of a U and wound wire around it, as in the picture and let a current of electricity flow through the wire. You would find that while the current is flowing (and no longer) the iron would be a magnet. Stop the current and the iron is iron and nothing more. You can see an electro-magnet working in any telegraph station. The bell that rings when an electric push button is touched is an electric bell. Its hammer is moved by an electro-magnet. (See page 90.)

MACHINES.

The Pulley.--A pulley like the one in figure 95 is often used to change the direction in which a rope is led. A pull of one pound on the rope will lift one pound and no more.

FIG. 95. A common pulley.

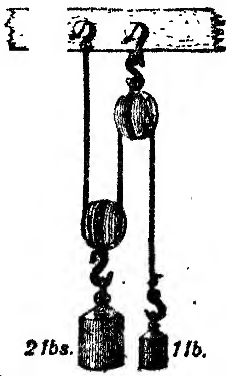


FIG. 96. These two pulleys are rigged so that a pull of one pound on the right-hand rope will raise two pounds attached to the left-hand pulley. (Try it.)

FIG. 97. A stone raised by a crowbar used as a lever. The point where the crowbar rests on the ground is called the *fulcrum* of the lever—the point about which it turns.

The Lever.—Any stiff bar—a crowbar, for instance—is a lever. By using a lever you can move a stone entirely too heavy to be moved by hand.

FIG. 98. A little boy on the long end of the see-saw balances a heavier boy on the other end.

A common pair of scales is a lever in which the two arms are equal. One pound in either scale-pan balances one pound in the other. The *fulcrum* of the beam is its middle point.

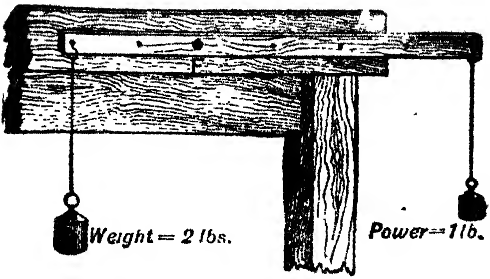


FIG. 99. A weight of one pound can be made to balance a weight of two pounds if it is hung at the end of a lever twice as long. (Try it by making a stick with holes every six inches, as in the picture, and putting a round iron nail (*F*) for the stick to move on.) Put the pin in different holes and see what weights will balance each other. The point *F* is the fulcrum.

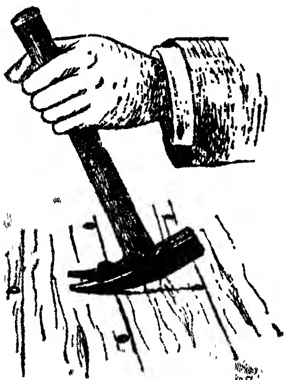


FIG. 100. A hammer: A lever with a short arm near the nail—the *fulcrum* is the point where the hammer touches the floor—and a long arm from the floor to where your hand takes hold of the handle.

A hammer is a lever when you use it in pulling out nails. A pair of scissors, of pinchers, of nut-crackers, are levers. The fulcrum of each one is the place where the two parts are joined together. A butcher's steelyard is a lever in which a little weight at the end of a long arm balances a larger weight at the end of a shorter arm.

The Inclined Plane.—A weight too heavy to lift

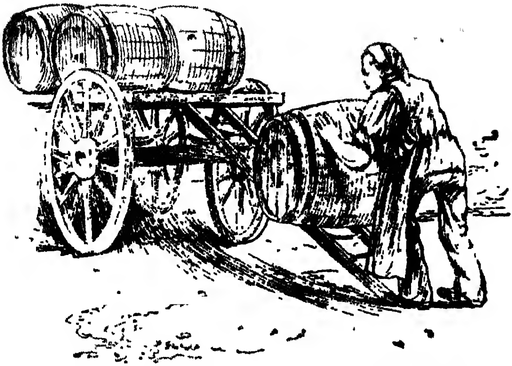


FIG. 101. A barrel too heavy to lift may be rolled up an inclined plane.

may be rolled or slid up an inclined plane. The work is done a little at a time. A railway can be

FIG. 102. A railway on an inclined plane in the Rocky Mountains. The altitude is conquered gradually.

laid up a mountain by making it curve so that the mountain is climbed a little at a time.

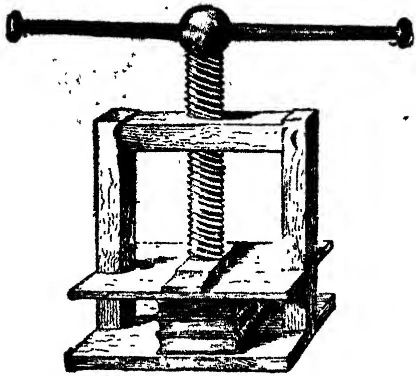


FIG. 103. A screw-press: By turning the screw a great pressure can be put upon the books—a little at a time.

The Screw.—A hole can be bored in a piece of hard wood by a gimlet when you cannot possibly make a hole by a smooth straight brad-awl. The screw is made up of an inclined plane wound round a straight line. It enters the wood gradually—a little at a time.

The Common Suction Pump.—This picture and the three following it explain the way in which the common pump raises water from a well.

In the picture I. the pump is empty. There is no water above the level of the top of the well. We wish to raise the water as high as the nozzle of the pump. How shall we do it? Recollect that the air—the atmosphere—is pressing on the

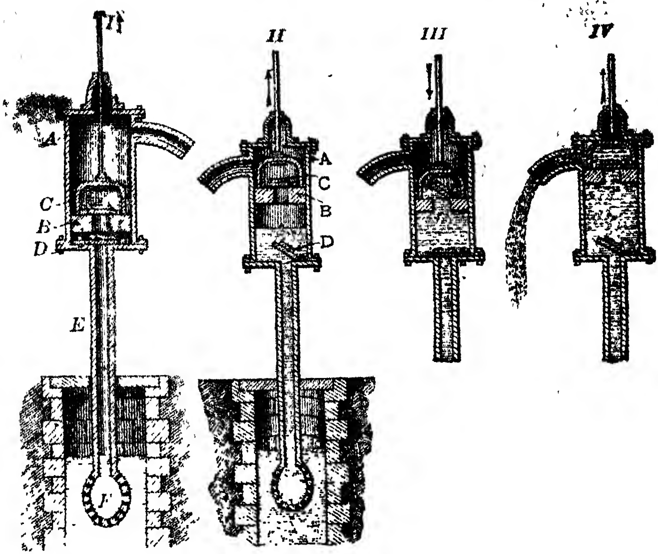


FIG. 104. *I.* A common pump. Its barrel is empty of water but full of air. A *suction pipe* (*E*) with a strainer (*F*) on the end of it leads down to the water in the well. At the top of this pipe is the *suction-valve*—a little door opening upwards (*D*). Above this is the *pump barrel* (*A*) in which the *piston* (*B*) works air-tight. The *piston-valve* (*C*) is a little door opening upwards. The piston is moved up and down by the pump handle (not drawn in the picture).

FIG. 105. *II* A common pump: The piston is moving upwards. When the piston has reached the top the barrel of the pump will be nearly full of water.

The upper valve will be shut, the lower one open.

FIG. 106. *III.* A common pump: The piston is now moving downwards. Its valve is opened and some of the water rises above the piston.

FIG. 107. *IV.* A common pump: The piston is now moving upwards, and some of the water in the barrel has been lifted high enough to flow from the spout.

upper surface of the water in the well and that the suction-pipe (*E*) and the whole pump barrel is full of air pressing down. Air, like all heavy things, presses downwards by its weight. If we can take this air out, the air over the well will press the well-water up, just as the quickskilver is pressed up in the barometer (see page [illegible]).

II. Let us raise the pump piston then. As this rises its piston will lift all the air above it. Below the piston the barrel will be empty of air and the water from the well will rush up and fill it. The air above the well-water presses it up.

BOOK III: METEOROLOGY.

The Atmosphere.—The Earth that we live on is composed of land and water and surrounded by an atmosphere of air. The land and water we can see, but the air is invisible. We know it is there, however, because clouds float in it just as corks float in water. The winds are nothing but air moving past us.

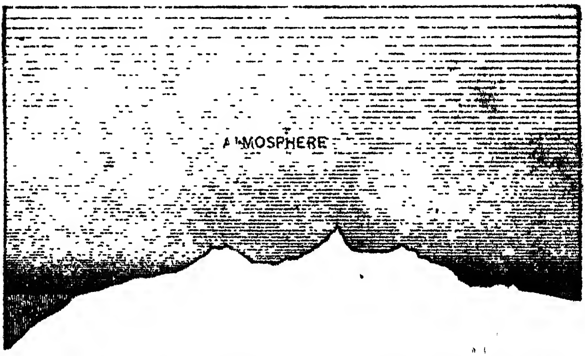


FIG. 108. The atmosphere is an ocean of air lying above the land and sea. We live at the bottom of the ocean of air just as some fishes live at the bottom of the ocean of water.

The higher you go in the atmosphere the less air there is. It is easy to breathe anywhere near the level of the sea. On the top of a mountain a mile high (5,280 feet) you begin to feel that there is not air enough; on a mountain two miles high you feel this very distinctly: on a mountain three miles high it is very difficult to breathe; and in the Andes or Himalaya mountains, where men have gone as high as four miles, it is hardly possible to breathe at all. Men have gone somewhat higher than this in balloons; and the higher you go the less air there is. Even birds do not fly more than four miles high.

Height of the Atmosphere.—Shooting stars do not begin to burn until they have come from space well inside the Earth's atmosphere (see page 39), and it has been proved that some of them begin to burn about 75 miles above the Earth's surface—therefore the atmosphere must extend at least as high as 75 miles. There is *some* air at that height, though very little indeed.

Air is a Mixture of Oxygen and Nitrogen Gas.—Chemists have proved that air is chiefly a mixture of oxygen and nitrogen gas, together with some other gases and with the vapor of water. Without the oxygen men and animals could not live. They need it to breathe.

Air is Heavy.—The simplest way to prove that air has weight is to take a tight box with a stop-cock and to weigh it when the stop-cock is open and it is full of air, and then to pump all the air out of the box and to weigh it after the stop-cock is closed. A cubic foot of air (that is the air in a box 12 × 12 × 12 inches) weighs a little over an ounce at the level of the sea. A cubic foot of water weighs about 67 pounds.

The Weight of the Atmosphere.—Each cubic foot weighs something. Near the level of the sea a cubic foot weighs more than an ounce; higher up, it weighs less; higher up still, it weighs less still. Imagine a tall column of air reaching from the ground to the top of the atmosphere (see Fig. 109) and instead of thinking of cubic feet let us think of cubic inches (1728 cubic inches make a cubic foot). The base of the column (*AB*) on the ground will be *one square inch*. On the top of that is a cubic inch of air pressing down by its weight; on the top of that another; and then another; and so on. It will be proved in the next paragraph that the weight of each and every such column of air is about fifteen pounds. Each and every square inch of the Earth's surface and of the surface of everything up on the Earth is pressed about fifteen pounds. The pressure is not only downwards but sidewise, too, because gases and liquids press equally in all directions.

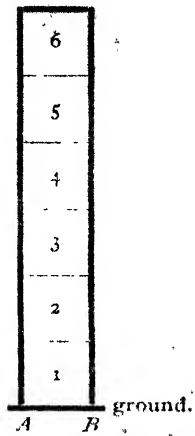


FIG. 109. The atmosphere presses the surface of the ground about 15 pounds on every square inch.

FIG. 110. Fill a tumbler partly full of water, cover it closely with a piece of writing paper, hold the paper with your hand and turn the tumbler over. Now take your hand away and the paper will stay in place. The weight of the water is pressing it down, but the air outside the tumbler is pressing it up and keeps it in place. (Try it — you may have to try several times in order to get the paper to fit tight enough to keep the air out of the tumbler.)

FIG. 111. Wet a piece of leather tied to a string (a sucker). Press it tight to a piece of wood. You can lift the wood. Why? Because the air presses the sucker with a pressure greater than the weight of the wood. If it did not, the wood would fall.

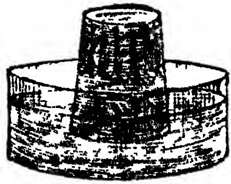


FIG. 112. Fill the tumbler as in Fig. 110, cover it, turn it over, put it in a basin of water, and carefully draw the paper out. The water in the tumbler will stand **above** the level of the **water** in the basin. Why? Because the air is pressing on the water in the basin and *not* on the water inside the tumbler.

The Barometer.—Why does the quicksilver stand in the tube about thirty inches above the quicksilver in the basin? (Fig. 113.) Because the air is pressing down on the basin and forcing the quicksilver upwards. It goes upwards a certain distance (about 30 inches) until the weight of the quicksilver in the tube, pressing downwards, just balances the pressure of the atmosphere upwards. If the glass tube is one square inch in area the quicksilver in it will weigh 15 pounds. Therefore the pressure of the air (which is balanced by this weight) is 15 pounds on a square inch: on this square inch and on every other one near the level of the sea. If you try this experiment on a mountain the quicksilver column

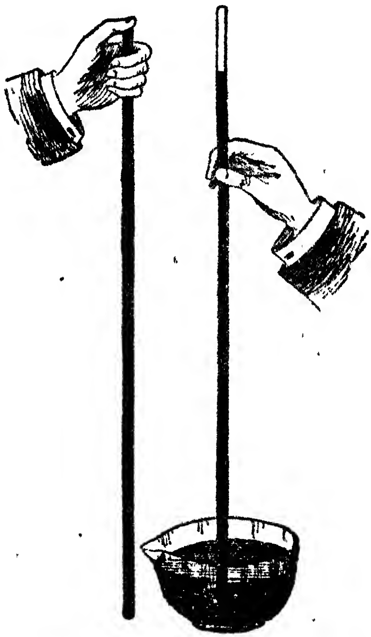


FIG. 113. Fill a tube closed at one end and about 34 inches long completely full of quicksilver; there will be no air in it. Cover the tube with your thumb. *Carefully* and *slowly* turn the tube upside down and put the end of it in a basin of quicksilver. Now take away your thumb. The quicksilver will stand about 30 inches high in the tube.

will not be so high; it will weigh less: because the pressure of the atmosphere (which it just balances) is less.

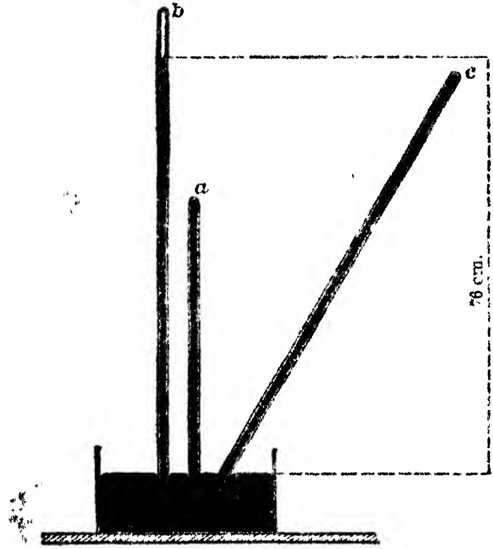


FIG. 114. In order to have an empty space above the quicksilver the barometer tube must be more than 30 inches long and it must stand upright.

Measurement of Heights by the Barometer.—If you are at the level of the sea the barometer will stand at about 30 inches. If you go up in a balloon or ascend a mountain there will be less air above you and the barometer will stand lower, consequently. On a mountain 7,000 feet high the barometer will stand at about 24 inches. A balloon has carried men as high as 31,500 feet (nearly six miles) and the barometer stood at $7\frac{1}{2}$ inches. There was not air enough to keep the balloonists alive. They breathed oxygen carried up with them in metal boxes. The heights of mountains are usually measured by barometers, not by levelling.

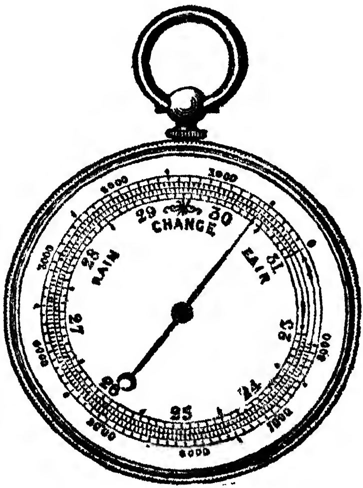


FIG. 115. An Aneroid Barometer, which measures the pressure of the air not by the height of a quicksilver column but by the changes in shape of a metal box (inside the outer case). The box is empty of air, and is sealed tight. As the air presses upon it it changes shape. The needle is arranged so as to mark the changes and to tell the height at which a quicksilver barometer *would* stand (see the inner circle of figures in the picture). The outer circle of figures shows how high above the level of the sea you are when the barometer points at each figure. When you are at the level of the sea the barometer stands at about 30 inches.

At 2,000 feet altitude the barometer stands at about 28.5 inches.
At 4,000 feet altitude the barometer stands at about 27.0 inches.

At 6,000 feet altitude the barometer stands at about 25.0 inches.
At 8,000 feet altitude the barometer stands at about 23.0 inches.

The Barometer is a Weather-Glass.—The barometer at the level of the sea usually stands at about 30 inches: in very fine clear weather it often stands higher; in very bad weather it stands between 28 and 29 inches. By watching the barometer you can tell something about the weather you are going to have. If the barometer is rising it is likely that the weather is going to be fine. If the barometer is falling below 29 inches it is likely that you will have rain (see Fig. 115, where the words are written on the dial-plate).

U. S. Weather Bureau Predictions of Weather.—In Washington there is a Government office called the Weather-Bureau. Several times a day this central office receives telegrams from cities all over the country telling the height of the barometer, of the thermometer, the direction and force of the wind, etc., at each and every one of the cities—at San Francisco, Denver, Omaha, Chicago, St. Paul, New Orleans, Mobile, Charleston, New York, Boston, Bangor for instance. Several times a day all these things are marked on a map.

Every few hours a weather map is made and the tracks of storms are drawn. Therefore the Weather Bureau can tell us beforehand when we are likely to have a storm. Farmers can take care of their crops in time; fruit-growers are warned of frosts; railway managers know when to expect snow; sailors know when dangerous winds are to be feared. The Weather-Bureau predictions are useful in a thousand ways.

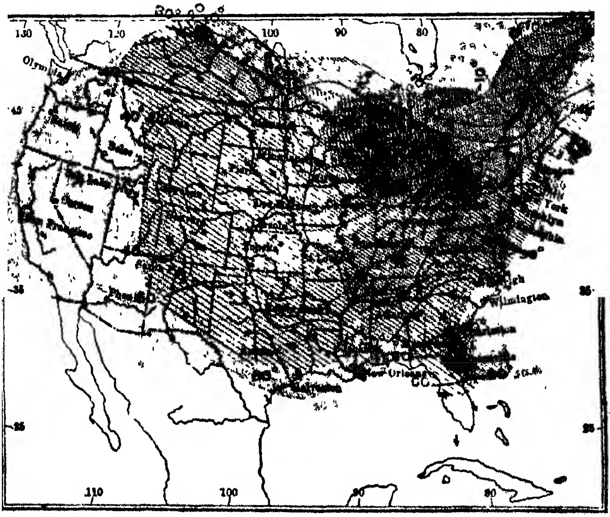


FIG. 116. One of the Washington weather-maps.

The red lines join places where the barometer is the same.

The blue lines join places where the thermometer is the same.

The reddest regions have the highest barometer.

The bluest regions have the lowest temperature.

The dotted regions are being rained on.

The lit' : arrows fly *with* the wind (point to the place towards which the wind is blowing).

The red figures give the height of the borometer.

The blue figures give the height of the thermometer.

The long dotted line from Manitoba to St. Paul shows the track of a storm moving eastwards.

Water-Vapor.—The air contains moisture—vapor of water—which is invisible, just as steam is invisible. Most of this moisture comes from the sea. Invisible vapor rises from the surface of the ocean into the air. We cannot see it, but we can prove that it is there, in this way:

FIG. 117. Drops of water will condense on the outside of a glass of ice-water (Try it.) The little drops on the outside come from the warm air of the room.

We know, in the first place, that warm air can hold more water-vapor in every cubic foot than cold air can hold. If we cool any mass of air some of the water-vapor in it will be squeezed out by the cold.

If you are in a warm room on a cold day you will see that the cold window glass is covered with moisture. The air near the glass is cooled and some of its vapor of water is condensed in drops on the panes.

Mists and Fogs.—If warm air with plenty of invisible moisture in it is blown by the wind across a cool valley or lake some of its moisture becomes visible as mist or fog.

Dew.—Some of the moisture of the air condenses upon cold solid bodies and we call that visible moisture *dew*. You can see it in the morning before sunrise covering bricks, the grass, plants, with thousands of little drops of water. When the sun gets high all the air becomes warmer and the visible dew is taken into the air as invisible vapor. A tumbler full of ice-water held in a warm room will soon be covered on the outside with hundreds of fine drops of water (see Fig. 117). Why? These drops do not come *through* the glass from the ice-water; they come from the invisible moisture in the air of the room which is cooled because it is near the cold tumbler. (Try it.)

Frost instead of dew results when the temperature is below the freezing point.

FIG. 118. Clouds along the (cold) face of a cliff in the Yosemite Valley in California.

Clouds are formed just as fogs are formed by the cooling of the air and moisture by the meeting of cold and warm currents, or otherwise. We call them fogs when they are near the surface of the Earth, clouds when they are high above it.

FIG. 119. Cirrus clouds. Such clouds are usually high up in the air—about five to six miles. They are formed of very small crystals of ice—frozen moisture.

Rain.—The very small water drops in a cloud often unite to make larger drops which fall in rain.

Hail.—If they are frozen on their way down we call the frozen rain drops hail.

Snow is frozen water-vapor, not frozen rain drops. If you look at snow flakes with a microscope, or a strong magnifying glass they always have the shape of a six-sided crystal. (Try it.)

Sleet.—If the falling snow flakes are driven about by the wind they lose their shape and they fall as sleet.

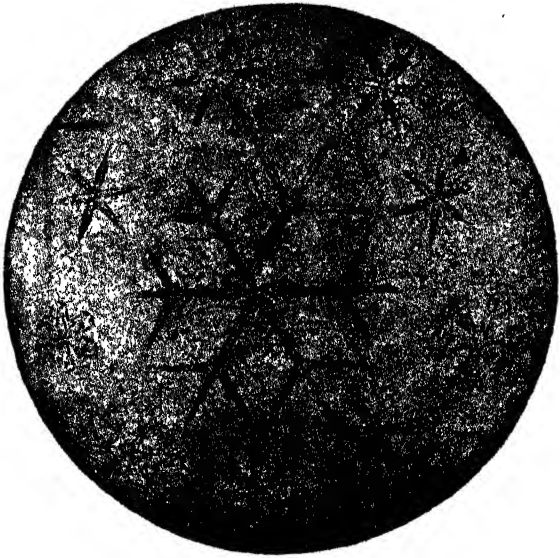


FIG. 120. Photograph of snow flakes.

The Rainfall of the United States.—The amount of rain (and melted snow) falling at different cities in the United States is measured in every storm, and the whole amount that falls in any year is the annual rainfall for that year. It varies from year to year at the same place, but not *very* much. At New York, for instance, the annual rainfall is usually more than 40 and less than 50 inches. That is, if all the rain of a year that fell into a barrel were kept it would more than fill a barrel 40 inches high. Study the map (Fig. 121) carefully and see what it means.

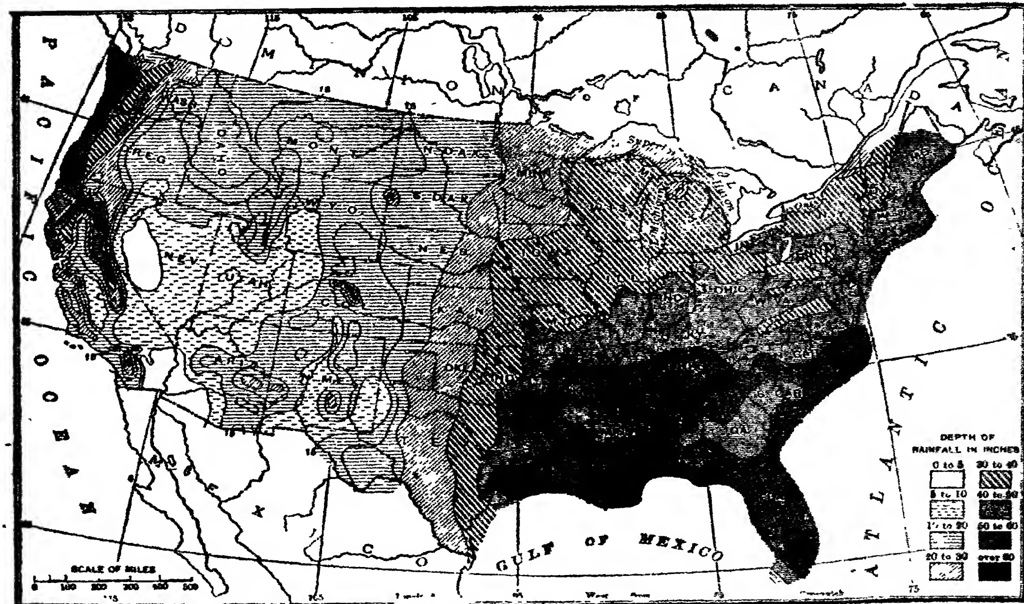


FIG. 121. The annual average rainfall of the United States. Read the legend of the map carefully and compare it with the chart. Such a map is important. Wheat can not be raised on land where the rainfall is less than about 18 inches, unless, indeed, the land is artificially irrigated.

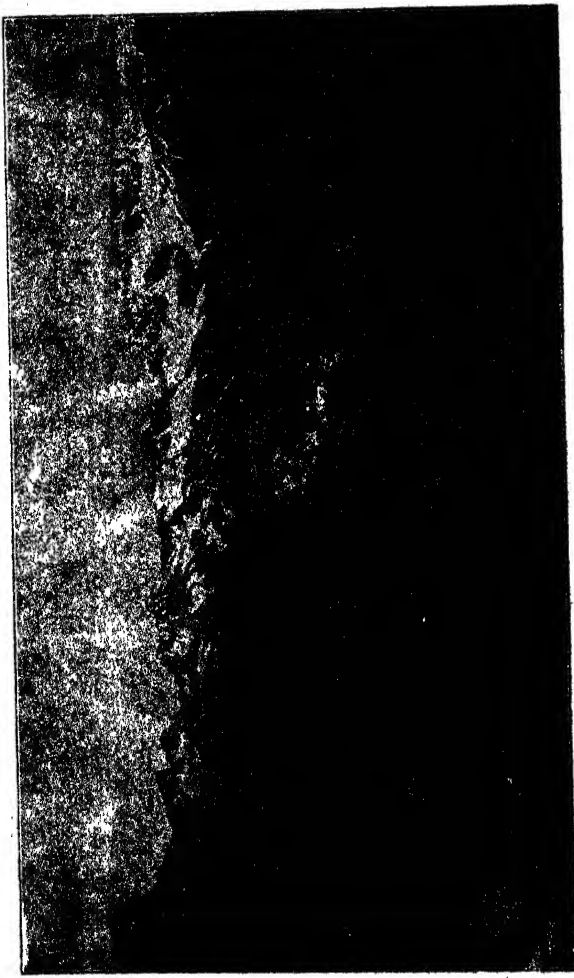


FIG. 122. The snow-line in the Rocky Mountains.

The Snow-line.—On very high mountains the snow never melts even in tropical regions. In the Arctic regions the snow never melts even at the level of the sea. The line above which the snow never melts is called the snow-line. In our Rocky Mountain regions it is about 13,000 feet above sea-level.

The Rainbow.—A beam of white light that leaves a prism is spread out into the colors of the spectrum (page 77). White sunlight reflected within rain drops makes the rainbow.

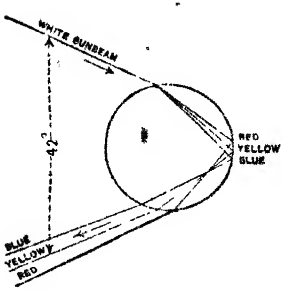


FIG. 123. A sunbeam of white light leaves a rain drop as a beam of colored light.

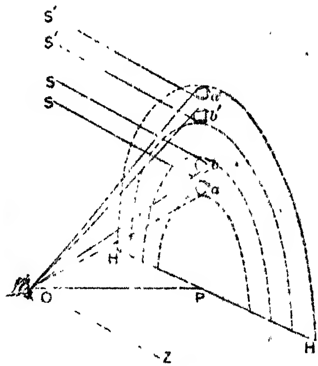


FIG. 124. The rainbow. It is formed by parallel rays from the Sun (*S*, *S*, *S'*, *S'*) refracted by rain drops (*a*, *b*, *a'*, *b'*) entering the eye. There are often *two* bows. *HH'* is the horizon.

Halos.—Most halos are formed by the light of the Sun (or Moon) refracted by crystals of ice in the upper air.

BOOK IV: CHEMISTRY.

CHEMISTRY is the science that tells us what things are made of; and it is useful in all kinds of manufactures. If you want to make gunpowder, or bread, to tan leather, or to make good steel, you must use a receipt that chemists have found out. The best way to understand chemistry is to make a few experiments.

The teacher should prepare the apparatus and try the experiments beforehand, and repeat them before the class. As the subject is not an easy one the experiments chosen are purposely made simple. Here, as elsewhere, it is sought to inculcate principles and to teach methods first of all. Little more than this can be done with children who have had no formal instruction in chemistry.

The following materials are needed. Every bottle should be plainly labeled.

In small glass-stoppered bottles:

Sulphuric Acid, Nitric Acid, Hydrochloric Acid, Acetic Acid.

In cork-stoppered bottles:

Sulphur, iron wire or filings or tacks, copper wire or filings or tacks, zinc wire or filings or tacks, quicklime, chalk crayons, scraps of zinc, scraps of pure lead, gunpowder, oxyd of manganese, sulphur matches, common table salt, phosphorus, fragments of marble, niter.

A pair of scales, a few glass tumblers and dishes, corks, a glass stirring rod, filter paper, a spirit lamp, a pane of window glass, glass jars, will be needed also.

Physical Changes: Solutions.—A pinch of common table salt is *dissolved* in a tumbler of water. The salt, which is a solid, becomes invisible in the liquid water. It is invisible, but all of it still remains in the water. If the solution is poured into a flat dish and set on a hot stove, the water will go off in steam and vapor, and will leave the solid salt in the dish. (Try it.)

Mixtures.—Mix powdered sulphur with iron filings by shaking them together in a box. A magnet will attract the iron filings and not the sulphur, and the two things can be separated in this way. (Try it.)

When salt is dissolved in water you can get the salt back again by heating the water; neither salt nor water is lost or changed. And when sulphur and iron are mixed you can separate them by a magnet. Neither is altered.

Combination.—But there are many things which *combine* when they are mixed together. You put in two things and they combine to make a third thing different from either.

Sulphate of Iron.—For instance, take one part (by weight) of iron wire, two parts of strong sulphuric acid in four parts of water and mix them. The acid and the iron will combine, and the iron will disappear.[1] Now filter the fluid and set it on a hot stove in a flat dish. The fluid will evaporate and will leave beautiful green crystals of sulphate

[1] If the mixture is heated the action will be more rapid.

of iron—green vitriol, so called. The acid and the iron have combined to make a third thing—green vitriol—different from either. (Try it.)

Sulphate of Copper.—Or again, take one part, (by weight) of copper wire, with ten parts of strong sulphuric acid (and no water). Mix them and boil the acid over a lamp until gas escapes rapidly. Let the mixture cool and pour off the liquid carefully. Add water to the residue and evaporate the solution over a fire. Beautiful blue crystals of sulphate of copper—blue vitriol—will remain. The acid and the copper have combined to make a third thing—blue vitriol—different from either. (Try it.)

Sulphate of Zinc.—Or again, take two parts (by weight) of zinc scraps and put them with three parts (by weight) of sulphuric acid to which there has been added ten parts of water. (Do not heat it.) When the action ceases you will have a liquid. Evaporate it over a fire and crystals of sulphate of zinc will remain. Two things have combined, and a third thing has been made, different from either of them. (Try it.)

Carbonate of Lime.—A piece of chalk is made up of two things, namely, carbonic acid and lime. Chalk is carbonate of lime. Pour some diluted sulphuric acid on the chalk. The carbonic acid, which is a gas, will be driven off, in bubbles, by the sulphuric acid, and sulphate of lime will remain. (Try it.) It is as if lime were a prisoner and the carbonic acid a soldier holding him. Sulphuric acid is a stronger soldier and takes the prisoner away.

Chemical Affinity.—The sulphuric acid has a stronger *affinity* for (liking for; fondness for) lime than the carbonic acid and always drives it off and takes the lime prisoner in its turn. Vinegar is an acid (acetic acid). It, also, has a stronger *affinity* for lime than carbonic acid has. Pour some strong vinegar on a piece of chalk (carbonate of lime) and the carbonic acid gas will fly away in bubbles and leave acetate of lime. (Try it.) It is just as if lime *liked* to be a prisoner of acetic acid rather than of carbonic acid.

Lime has a greater *affinity* for acetic acid, than for carbonic acid, the chemists say. It is by studying these likes and dislikes of the metals chemists find out the easiest and the cheapest ways to manufacture them.

Chemical Manufactures.—All sorts of things, gunpowder, glass, soap, cheese, illuminating gas, bread, etc., are made by receipts that the chemists have invented.

Gunpowder is a mixture of charcoal, sulphur and niter.[1] These three things are mixed—they are not combined until the gunpowder is fired off. Then they suddenly combine and make a gas. The gas in the bore of the gun pushes the bullet out quickly. The best gunpowder is that which gives the most gas, and chemists have taught us

[1] Niter is a combination of potassium and nitric acid.

exactly how to make it. A cannon ball can be shot out at a speed of 2,500 feet a second now-a-days; a hundred years ago it was not possible to shoot it out a quarter as fast.

Composition of Air and Water.—Our air—the atmosphere—is a mixture (not a combination) of two invisible gases called oxygen and nitrogen. Water is a combination (not a mixture) of two invisible gases called oxygen and hydrogen.

Oxygen.—Take a piece of oxyd of manganese. It is made up of oxygen gas combined with manganese, which is a metal. Heat it and the oxygen gas will go off in bubbles and can be collected under a jar. (Try it.)

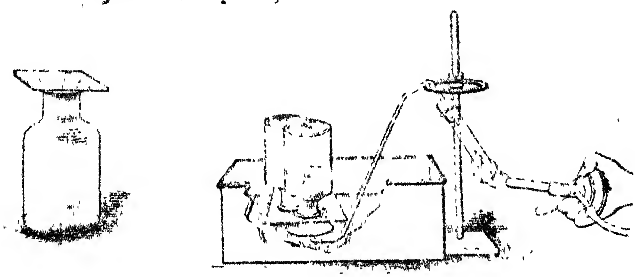


FIG. 125. Preparation of oxygen gas. Heat powdered oxyd of manganese in a tube about one-third full. The oxygen gas will be driven off by the heat and can be collected over water in a jar turned upside down. Afterwards slide a sheet of glass under the jar so as to close it and keep the gas till it is wanted for other experiments.

Nitrogen Gas can be prepared by burning a bit of phosphorus[1] (not bigger than a green pea)

[1] Handle the phosphorus with pincers—forceps; never touch it with the hands as it produces very bad sores.

under a glass jar containing air. Air is oxygen and nitrogen mixed together. The phosphorus burns up the oxygen of the air and all that is left in the jar is nitrogen gas.

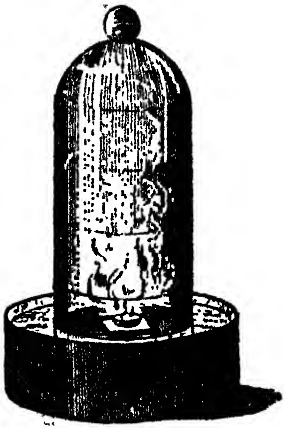


FIG. 126. Preparation of nitrogen gas. Float a little phosphorus in a saucer on a small piece of wood in a jar of water. Cover it by a bell-jar. Set the phosphorus on fire. It will burn up all the oxygen in the bell-jar and leave only nitrogen. Slip a pane of glass under the bell-jar while it is in the water and keep the nitrogen gas till it is wanted for use.

In 100 pounds of air, 23 pounds are oxygen and 77 pounds are nitrogen. This is the air we breathe, and it is the oxygen in the air that keeps us alive. If an animal (a mouse for instance) is put into a jar of nitrogen gas it dies. The nitrogen gas does not kill the mouse; it is the lack of oxygen that kills it. A match will not burn in nitrogen. (Try it.)

Preparation of Hydrogen:

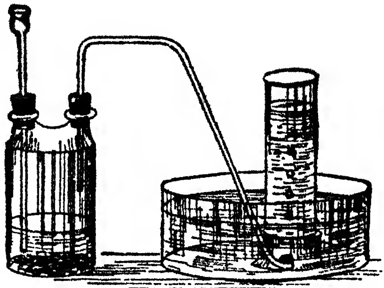


FIG. 127. Preparation of Hydrogen. The left-hand jar contains scraps of zinc in water. Through the straight tube with a cup at the top carefully pour in some strong hydrochloric acid. The liquid will begin to bubble all round the zinc and the bubbles will rise, go over through the bent tube and be caught above the water in the closed jar which has been turned upside down and set on a stand. These bubbles are hydrogen gas.

What has happened is this: the zinc has taken some chlorine from the hydrochloric acid (which is chlorine gas combined with hydrogen gas), and formed chloride of zinc, which stays in the first jar. The hydrogen gas set free has gone over in bubbles, and is collected in the right-hand jar.

N. B. This is a dangerous experiment, because if hydrogen gas mixes with air the mixture may explode. Two things must be carefully attended to: I The right-hand jar must be ***completely*** filled with water and then turned upside down so that no air remains at the top of it, above the water. II. The bent tube (which, in the picture, extends too far into the left-hand jar) must not be put under the right-hand jar for some little time after the acid is poured on the zinc—not until it is sure that all the air in the left-hand jar is driven off, and that nothing but pure hydrogen gas is coming through the tube.

Combustion.--Combustion is burning. When a match, or a piece of coal, burns there is combustion. Combustion is usually the combination of something with oxygen. When a match burns, the sulphur on its head combines with the oxygen of the air, and it makes a stifling gas.

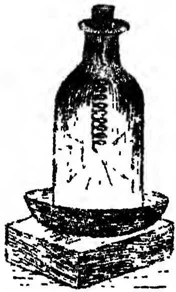


FIG. 128. Sulphur burned in oxygen. Fasten a spiral wire to a cork as in the picture. Heat the wire red hot and put it into some powdered sulphur. Light the sulphur with a match and remove the cork that stoppers a bell-jar of oxygen and put the cork with the spiral wire in its place. The sulphur will blaze brilliantly till it is all burned away. (Try it.)

When coal burns the carbon of the coal combines with the oxygen of the air and makes carbonic acid gas. The combustion (burning) is rapid in these cases. When iron rusts some of the iron combines (slowly) with the oxygen of the air and makes the oxyd of iron (iron-rust). When we breathe air into our lungs there is a slow combustion there. Part of our body rusts, as it were; the slow burning of our fat and food keeps the temperature of our body at about 98° Fahrenheit even when the air round us is at zero. The colder the air the more food we must eat to keep warm. That is the reason why the Eskimo eat fat and blubber.

Combustion in Oxygen.—Light a match and let it burn in the air and blow it out. While the end of the match is still glowing red put it into a jar of oxygen gas. The match will instantly burst into flame. (Try it.) Blow out the match and try it again and again.

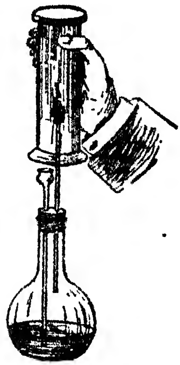


FIG. 129. Hydrogen burning in air. The bottle contains hydrogen gas. The left-hand tube is stopped up. The right-hand tube leads up inside an empty glass jar. Hydrogen gas will stream up this tube. Light it with a match and it will burn. It will combine with the oxygen of the air. *Hydrogen and Oxygen combined form water.* Notice the drops of water that condense on the inside of the glass. The teacher should try this experiment, using great care.

Hydrogen is the lightest of all gases and is exactly suitable for the filling of balloons. It takes fourteen cubic feet of hydrogen to weigh as much as one cubic foot of air, so that a balloon filled with hydrogen (a little toy balloon for instance) will float in the air.

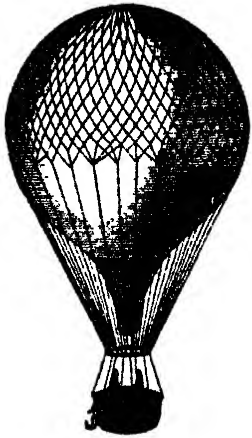


FIG. 130. A balloon. Hydrogen is expensive and most balloons are filled with common coal gas (illuminating gas).

Chemical Elements.—When a chemist sees a substance new to him, a mineral, for instance, the first thing he tries to find out is whether the substance is a combination of substances that he knows already. For example, he finds that salt is made out of chlorine (a gas) and sodium (a very light metal). Next he tries to separate chlorine into any other two substances. He cannot do it; or, at any rate no chemists have succeeded in doing it, so far. Neither have they separated sodium into any simpler things. Substances that cannot be separated into any simpler substances are called *elements*. Here is a list of the most familiar elements.

METALS.

Aluminum	Sodium
Calcium	Quicksilver (a liquid metal)
Copper	* Nickel
Gold	Silver
Iron	Tin
Lead	Zinc.
Potassium	

NON-METALS.

* Arsenic	* Iodine
Carbon	Nitrogen (a gas)
Chlorine (a gas)	Oxygen (a gas)
Hydrogen (a gas)	* Phosphorus
	Sulphur.

There are twenty-two elements named in this list. There are about seventy elements in all, but many of them are very rare. Ninety-nine hundredths of the substances on the Earth are made up of the eighteen elements in this list whose names are *not* marked *.

Every single thing on Earth that you can name is made up of one of these elements, or of a combination of two, three or four of them. And all that we know about the Sun, Planets, Stars and nebulæ leads us to think that they, too, are made up of the same elements.

Chemical Compounds.—Some of the substances that we see and handle on the Earth are elements (gold, silver, iron, etc.), but most of them are compounds—made up of two or more elements (salt, clay, steel, wood, leather, etc., are compound substances).

Clay is silicon, aluminum, oxygen and hydrogen.

Salt is chlorine and sodium.

Steel is iron and carbon and phosphorus and sulphur and nickel.

Wood is chiefly carbon, oxygen, hydrogen and nitrogen.

Leather is chiefly carbon, oxygen, hydrogen and nitrogen (combined in different proportions from wood).

Diamond is pure carbon.

Black-lead, in a pencil, is very nearly pure carbon.

Sugar is carbon, hydrogen and oxygen.

Human hair is carbon, hydrogen, oxygen, nitrogen and sulphur.

Indigo is carbon, hydrogen, nitrogen and oxygen.

Quartz is silicon and oxygen.

Granite is silicon, oxygen, aluminum, potassium or sodium.

Quinine is carbon, hydrogen, nitrogen, oxygen and sulphur.

Air is oxygen and nitrogen (*mixed*).

Water is oxygen and hydrogen (*combined*).

Human flesh—fat is carbon, hydrogen, oxygen; *lean* is carbon, hydrogen, oxygen, nitrogen, sulphur.

Milk is water (oxygen and hydrogen) containing fat (carbon, hydrogen, oxygen, nitrogen, sulphur).

Chemical Symbols.—Instead of writing the word oxygen out in full chemists use the symbol O to stand for it, and in a similar way they use other letters to stand for the other elements. These symbols always stand for *fixed weights* of the elements. O always stands for 16 parts, by weight, of oxygen. H always stands for one part, by weight, of hydrogen. Na stands for 23 parts of sodium. Cl for 35 parts of chlorine, and so on.

Symbols of the Elements.

Calcium is Ca.	Silver is Ag,
Gold is Au,	Zinc is Zn,
Iron is Fe,	etc.
Lead is Pb,	Sodium is Na,
Carbon is C,	Hydrogen is H,
Chlorine is Cl,	Nitrogen is N,
	Oxygen is O.

Chemists write the symbol for water H_2O, which means that in water there are 16 parts, by weight, of oxygen to two parts, by weight, of hydrogen. Sodium combines with chlorine to make common salt. Chemists write the symbol for salt NaCl, which means that it contains 23 parts, by weight, of sodium and 35 parts of chlorine. Sulphuric acid is H_2SO_4; nitric acid is HNO_3; hydrochloric acid is HCl; acetic acid is $C_2H_4O_2$, carbonic acid H_2CO_3.

Green vitriol is $FeSO_4$; blue vitriol is $CuSO_4$; marble is Ca CO_3; starch is $C_6H_{10}O_5$; cane-sugar is $C_{12}H_{22}O_{11}$; and so on.

This is a short way of writing; and it can be used for describing an experiment and for telling beforehand what third thing is going to be produced when two things are combined. For instance, the experiment on page 125 (to make blue vitriol) can be described in this way:

Cu +	H_2SO_4	= $CuSO_4$	+ H_2
(Copper)	(Sulphuric acid)	(Sulphate of copper = blue vitriol)	

and so on for other combinations.

BOOK V: GEOLOGY.

Geology is the science of the rocks. It tells how rocks were made in the first place, how they have been raised above the level of the sea, then crumpled up by earthquakes and pressure to make mountains, how they have been worn away by water and ice. The past history of the Earth is written in the rocks, and Geology tells how to read the history right. How old is the Earth? How does it happen to have its present shape? How long have men lived on it? Such questions as these cannot be answered without studying the rocks. We have to begin by studying the way in which water and ice make changes in the Earth's surface.

The Earth's Crust.—The crust of the Earth is the rock and soil of the land and the rock and clay of the ocean floors. No one knows exactly what is below the crust. The deepest wells and cañons are about a mile in depth. The hot lava from volcanoes does not come from very great depths. The only parts of the Earth that we ever can see or touch are the rocks of the thin outer crust. Draw a circle eight inches in diameter, and let it stand for the Earth. The thin pencil line that bounds it is wide enough to stand for the crust. Ninety-nine hundredths of the Earth's crust is made up of a dozen of the chemical elements see page 133) as carbon, oxygen, hydrogen, nitrogen, silicon, aluminum, sulphur, iron, etc.

Running Water Models the Shapes of the Hills and Mountains of the Earth's Crust.—If you look at a plowed field after a heavy rain you will see that it is all carved into small ravines and hills. The ground was soft and one rain was enough to do the work. The hard rocks of the mountains have been carved in the same way, only it has taken thousands of years and hundreds of thousands of rains to do the work.

FIG. 131. This map of a river and its branches might be a map of the little rivulets of water in a plowed field after a rain.

The softest rocks of a mountain are quickest worn away and the high peaks usually consist of the hardest rocks.

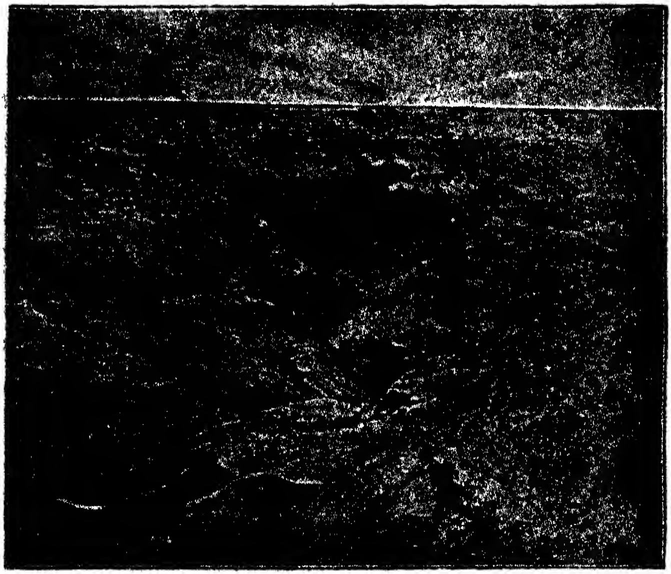


Fig. 132. A view in the "Bad Lands" of Dakota. The rain has carved all the slopes.

Ocean waves may wear away sea-cliffs several feet every year. There is a church in Kent, England, that was a mile from the shore in the time of King Henry VIII. (1509). In the year 1804 it fell into the sea. In three centuries the ocean had worked its way a mile inland.

FIG. 133. A high peak of hard rock. Deep valleys have been worn all around it by water and widened by glaciers.

Rivers Cut Deep Gorges in Rocks.—Everywhere we see rivers cutting their channels. The Niagara river has cut a deep gorge connecting Lake Erie with Lake Ontario. The river falls over

FIG. 134. A part of the gorge of the Niagara river.

a precipice and wears away the rock over which it falls about three feet every year. It has already cut a deep gorge about seven miles long. To do this work has required at least 12,000 years and probably more time. We can say then that any changes in the rocks that occurred before the

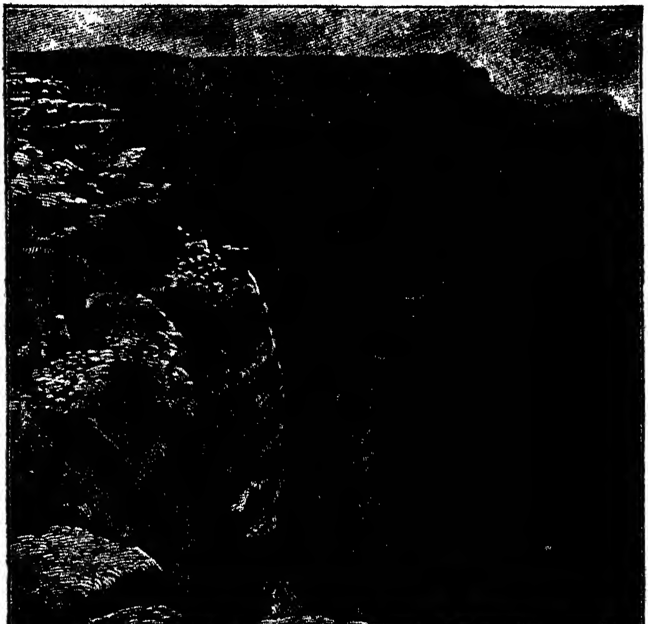


FIG. 135. *The Great Cañon of the Colorado River.*—This cañon is about 300 miles long and its depth is always as much as half a mile, and often as much as a mile. The river used to run on the surface of the ground. It has cut hundreds of miles of the length of its gorge down into and through hard rocks a mile in thickness. Imagine how long a time this work required.

Niagara river began to cut its gorge must have happened at least 10,000 years ago. It is in this way that time is measured in geology.

Rivers Carry Soil to the Sea.—The Mississippi river, for instance, carries enough solid material to the sea, every year, to make a hill 268 feet high and a mile square. Five thousand such hills would cover all the land drained by the Mississippi (its drainage-basin) one foot deep with soil. It will take the Mississippi five thousand years, then, to lower the level of its whole basin one foot. And, generally, we may say that all the continents have their levels lowered by rivers about one foot every five thousand years.

FIG. 136. A mountain brook. It can move quite large stones, especially in the spring when the brook is full.

Stones are Carried by Streams.—A stream whose current moves six inches in a second will carry fine sand along with it; gravel is carried if the current moves a foot in a second; stones as large as a hen's egg if the current moves three feet in a second. (Boys who live in the country can prove this for themselves.) Very rapid torrents move large bowlders.

Streams Sort Out Different Sizes of Stones.—A mountain torrent will carry quite large stones along with its current. When the stream leaves the hills and runs more slowly it drops the largest stones. It will carry gravel a long way, but by and by it drops the gravel too. As it runs more and more slowly, in a flat country, it may even drop the sand it is carrying. The different stones are sorted out, according to their weight, by the stream. If you put some sand in a basin full of water you cannot pour all the sand out with the water unless you give the basin a swirl to make the water move faster. *Then* it will pick up the sand. (Try it.)

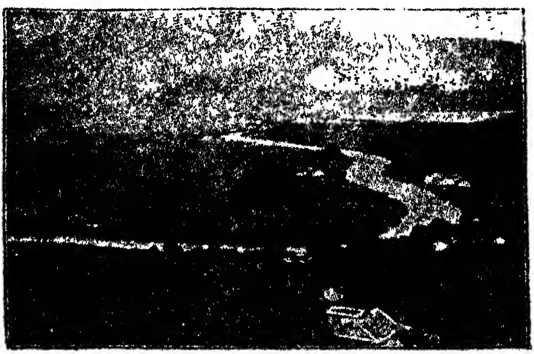


FIG. 137. A flood plain.

Flood-Plains.—When rivers are flooded by melting snows or heavy rains, they overflow their banks, and their waters, which carry sand and mud, spread out over the land on each side. In spreading out they run less swiftly, and drop some of the mud and sand and form a flood-plain. The mud that is dropped is called *sediment*—that is settlings.

FIG. 138. The delta of a river.

Deltas.— At the mouth of a river there are often several branches spreading out like the Greek letter *delta* (Δ). Every year much mud and sand is deposited by the river and if the current is strong they are carried out to sea and dropped on the sea bottom, where, in time, they are cemented into rock.

Sediments are Deposited in Layers (*Strata*).—If a river empties into a lake or into the sea it brings great quantities of sand, gravel, etc., and these settle on the bottom of the lake as sediments—settlings. They lie in layers one above another. The river runs faster in the time of spring floods than in the dry summer and so layers of gravel will sometimes lie over layers of sand. This goes on for centuries and centuries, and by and by, all these layers are cemented together and make a rock that is called a *sedimentary rock*. It is sandstone if the layers are of sand; limestone if the layers are made of the shells of dead animals that live in the ocean. *All sedimentary rocks are stratified—are in layers: and all rocks that are stratified* (in layers) *were originally made from materials sorted out by water.*

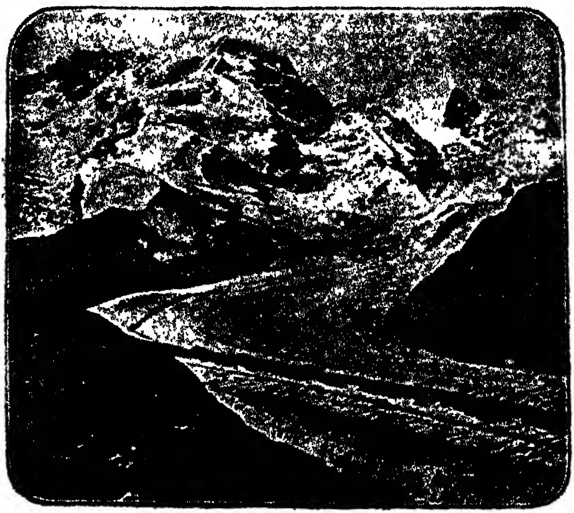


FIG. 139. A glacier in the Alps. From the snow-covered summits the glacier slowly moves downward like a river of ice. It carries with it all the rocks that fall on its surface and it grinds and polishes the face of the rocks in its bed.

Glaciers.—Snow falls on the tops of mountains in the winter and if they are very high it does not melt when the summer comes. Above the snow-line (see Fig. 122) there is perpetual snow. This snow slides downwards on the steep slopes and becomes packed into ice (as a snow ball can be packed, by pressure, into ice) and the ice, like a river, slowly flows downward between walls of rocks towards the valley below. At the lower end of the glacier the ice melts and forms rivers that are usually torrents. Glaciers flow like rivers, only very slowly, a few feet every day. If you drive a row of stakes in a line across a glacier like this:

Rocks . . | . . . . | . . Rocks
Glacier

in a few months the stakes will look like this:

Rocks . . | . . . . | . . Rocks
Glacier
↓

The four stakes on the rocks will not move, of course; the others move as the ice moves; the middle of the glacier moves fastest. (Why?)

Bowlders.—The glacier grinds against its rock walls and carries pieces of rock down with it. Bowlders fall on it and are carried down on its surface. Now-a-days we often find great bowlders in places where there used to be glaciers that do not exist any longer. We often can tell just where these bowlders came from because they must have come from ledges of the same kind of rock. This is one proof that glaciers used to exist in that place.

FIG. 140. Boulders on Cape Ann, Massachusetts. They were brought by an ancient glacier that has long since disappeared.

Glacier-Scratches.—The glacial river is heavy and presses hard against its bed and its walls. The stones in the ice are slowly rubbed along the stones of the walls and bed and glacial scratches are made. If you find a rock to-day with such scratches you may be sure they were made by an ancient glacier, although the glacier may have melted away centuries ago.

FIG. 141. Glacier markings on a rock in Iowa. There are no glaciers in Iowa now-a-days.

A glacier carries a great quantity of rock and dirt with it. At the lower end of the glacier much of this dirt remains when the glacier melts. Some of it is carried away by streams of course, but much remains. The glacier thus builds up at its lower end a peculiarly-shaped wall. Wherever you find such walls, now-a-days, was the lower end of an ancient glacier.

The Glacial-Period in the United States.—A great part of the United States was once covered by glaciers as Greenland now is. This was perhaps a hundred thousand years ago. Since then the climate has changed and the glaciers have melted. The ice sheet was, in parts, nearly a mile thick. It covered parts of Iowa, nearly all of Illinois and Ohio, all of New York and New Eng-

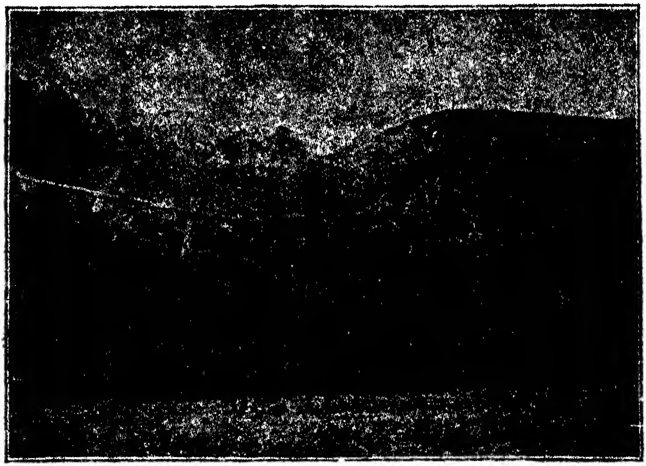


FIG. 142. A peculiar shaped hill (*a moraine* built by a glacier near Ithaca, N. Y. There are no glaciers in New York now.

land, and all of Canada. (Trace this region out on the map of the U. S., Fig. 121.) Bowlders, glacial markings and moraines now to be seen prove the existence of this ancient ice-sheet. Think what a different country America then was. Its plants, animals and men were all driven southwards by this ice-sheet. Its climate was very different. Nearly every one of the ponds and lakes in Canada and the northern United States has been formed by this glacial ice. The valleys of all the rivers were much changed too; though many of the rivers are older than the ice sheet. The ice sheet endured for thousands of years and had time to do much work. The great falls at Niagara were formed by it, probably.

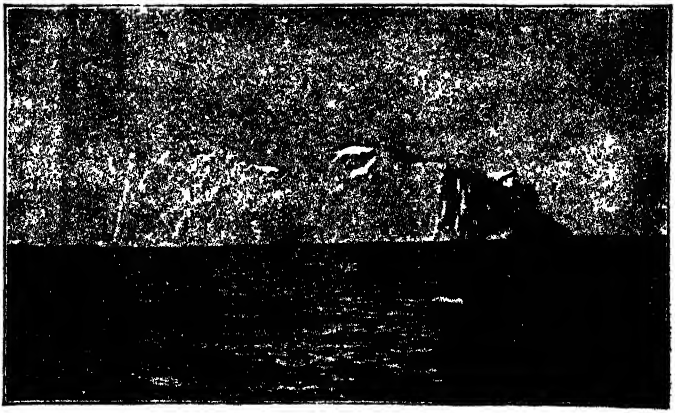


FIG. 143. An Iceberg from the Greenland glaciers. Seven-eighths of its mass are below sea-level.

Icebergs.—When a glacier ends in the sea, as many glaciers in Alaska and Greenland do, huge blocks of ice break off and float away. These icebergs are made of fresh water (why?) and they float so that only about one-eighth part shows.

Pack-Ice.—The salt water in the Arctic regions freezes, too, and makes fields of pack ice so thick that vessels can not penetrate it. It is often so jammed together by winds and currents that its surface is too rough for men to travel on. This is one of the principal reasons why it is so difficult to reach the north pole.

Soil is Rock that Has been Broken Up.—Take up some soil in your hands and you will find that while much of it is soft, it contains little crystals of sand, etc. These crystals are pieces of rock that has decayed and crumbled to pieces. Rub a pane of glass with these crystals and you will find scratches on it.

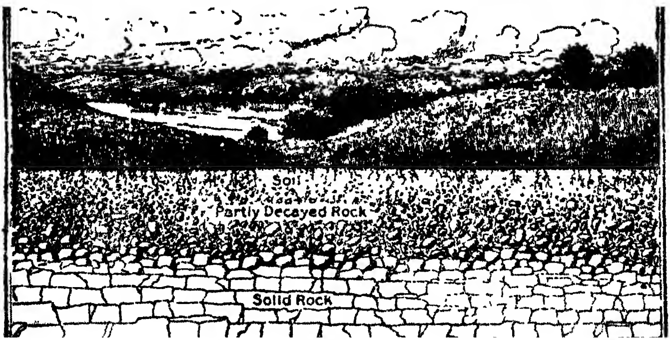


FIG. 144. A picture to show the soil and what is underneath it. On top is the soil; below that, rock partly decayed; below that again, solid rock. But this last has cracks in it. Water enters these cracks and bursts them apart when it freezes. Rocks are all the while decaying and making soil.

If you go deep down below the soil, anywhere on the Earth, you will find solid rock—below the oceans as well as below the continents.

In the gorges and cañons of rivers, in quarries, tunnels, and railway cuttings you can see the bed-rock, as it is called.

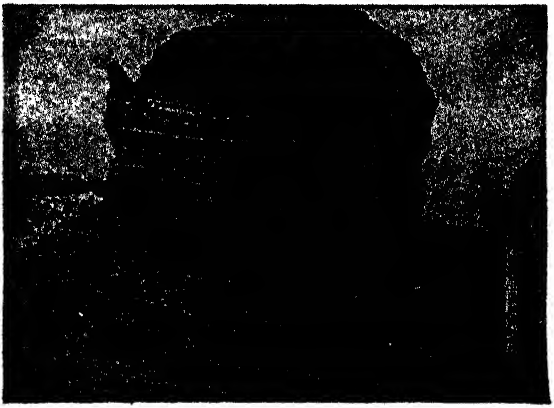


FIG. 145. A mass of stratified rock. The different layers (strata) are of different kinds. This rock was formed under water.

Different Kinds of Rocks.—Granite, lava, sandstone, limestone, marble, slate and coal are rocks. (Try to get a piece of each kind.) *Granite* rocks have been formed deep down in the interior of the Earth, where it is very hot, and where the pressure is very great. *Lava* is melted rock that has flowed out from a volcano. *Sandstones* are grains of sand that have been cemented together, under water. They are in layers—in *strata*. Most *limestones* have also been cemented together, in layers, under water, from the shells of small sea animals.

Nine-tenths of all the surface of the land is covered with stratified rocks. That proves that the continents were formed under the sea and then slowly lifted up.

Stratified rocks lie under all the oceans.

FIG. 146. A rock made of shells cemented together under water.

Granite is composed of three different minerals, quartz, feldspar and mica. You can see in a piece of freshly broken granite little crystals of hard quartz, and with your knife you can cleave off thin layers of shining mica (isinglass it is sometimes called). Feldspar is there, too, in small flesh-colored crystalline slabs. (Try to find these in a piece of granite.) All the granites were formed deep down in the Earth. The granites that we see have been uncovered by water that has worn away the rocks that once laid above them.

Limestone is made of granules of carbonate of lime cemented together. If you put a drop of sulphuric acid on limestone carbonic acid gas is set free in little bubbles.

Sandstones are grains of sand cemented together. Red sandstones are cemented by a compound of iron, and the air does not affect them. For that reason they make excellent building stones.

FIG 147. Photograph of two pieces of granite.

Slates are clay in layers each one like the slates that you use in school.

Clay.—When a crystalline rock is broken up into very fine grains and deposited under water we have a clay. The ocean bed, far from land, is, in great part, made of a reddish clay.

Crystalline Rocks and Crystals.—If you break a piece of marble you will see that the rock is made of a multitude of little shining crystals. Sugar, too, is made of crystals.

Precious Stones.—Diamonds (white), rubies (red), emeralds (green), sapphires (blue), topazes (yellow), amethysts (violet)—are all crystals.

FIG. 148. Obsidian—a lava rock like black glass. Pumice is another kind of lava.

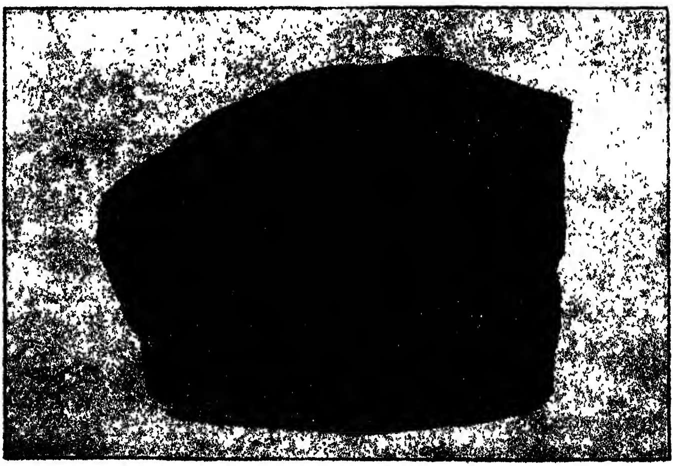


FIG. 149. A piece of sandstone rock.

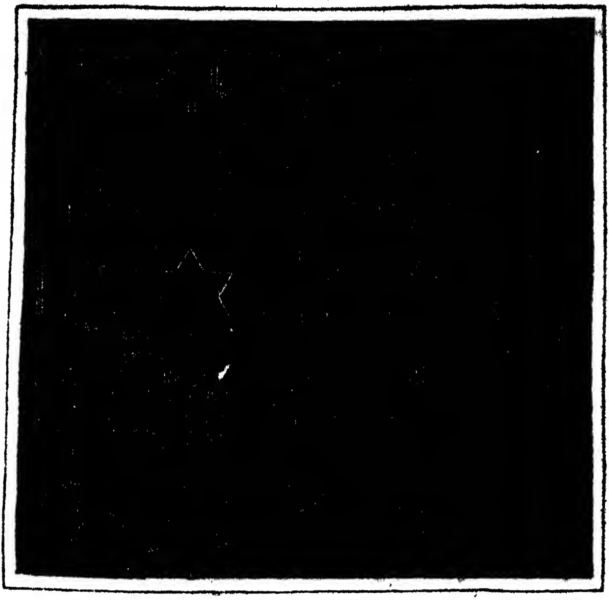


FIG. 150. Snowflakes crystallize into six-sided forms.

Dissolve a quantity of salt in water, and then set the water in a metal pan on a stove so that the water evaporates rather slowly. Crystals of salt will form and will gradually grow larger. (Try it.) Every one of these crystals, large or small, is a cube. Salt crystals are all of one form, just as elephants are all of one form, whether they are large or small.

Dissolve a quantity of sugar, or alum, in boiling water and set it away to cool. Hang some threads of string in the solution, and when it cools you will find the string covered with shining crystals. (Try it.) Snow is crystallized water.

Elevation and Depression of the Land.—All stratified rocks, we know, were formed under the ocean. How is it that we find them making the land? Millions of years ago they were formed;

FIG. 151. A crystal of quartz. Quartz crystals usually have a shape like this.

slowly—a layer at a time. It required millions of years to make them. During this long period the crust of the Earth has suffered many changes. Some parts of it have been lifted up; some parts depressed. On mountains, thousands of feet above the ocean, we still find shells of sea-animals bedded in the rock. When the shells were deposited, the tops of those mountains were under water. In Lake Baikal, which is now 1,600 feet above the sea, there are living seals of the same species as those of the Arctic Ocean. Their ancestors came there before the glacial epoch, when Siberia was under water. The interior of the country was then lifted up leaving this lake, and the seals have continued there to this day. They are living evidence of the rise of this country from the ocean. Even now the coasts of Sweden are rising and you find sea beaches there 600 feet above the present sea level. Other coasts are sinking.

There is a temple to Jupiter built by the Romans near the seashore about two thousand years ago. Three of its columns are still standing and in them you can still see sea shells which have bored into the marble. When these borings were made the floor of the temple must have been at least twenty feet under water. It was above water when the Romans built it; below water when the sea shells were boring; and it is almost above water now. So that here is a certain proof that the land where the temple stands has been depressed twenty feet and raised again in the last two thousand years. There are many other proofs of the same kind and they all show that in the millions of years during which the Earth has lasted the crust has been elevated and depressed many times, very differently at different places, of course.

All the granites of the Rocky Mountains were formed deep down in the very hot interior of the Earth and have been raised by the crumpling of the crust. All the sandstones and limestones of the country were formed under water and have been raised to their present levels by crumplings of the Earth's crust. Sometimes the lifting was gentle and gradual; sometimes they were raised by violent earthquakes.

FIG. 152. Stratified rocks tilted. Originally the layers were horizontal. During some crumpling of the Earth's crust they were turned on edge.

The Stratified Rocks are About Five Miles Thick.—Few rock walls are more than a mile high. How can we know, then, that the stratified rocks of the Earth's crust are at least five miles thick? In the crumpling of the crust the stratified rocks are sometimes turned on edge, as in Fig. 152. We can then actually measure their thickness.

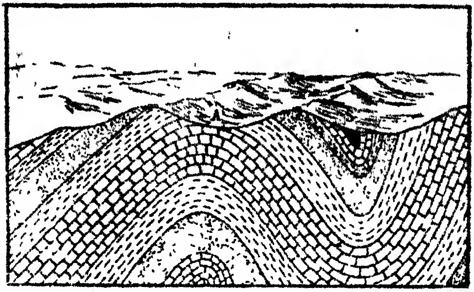


FIG. 153. A series of layers of rocks of different kinds that were originally horizontal and that have been tilted up on edge.

Crumpling of the Earth's Crust:

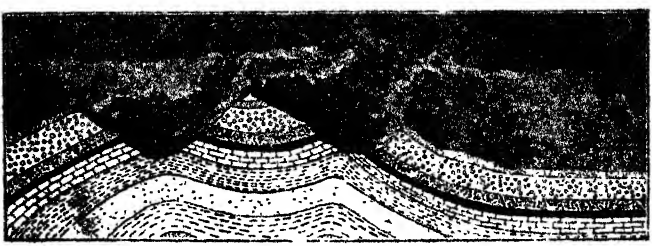


FIG. 154. A picture to show how mountains are sometimes formed by crumplings of the Earth's crust, and how rivers flow in the valleys. The black stratum is coal. It would never have been found if the layers of rock had not been crumpled.

Mountains are usually formed by the crumpling of the crust of the Earth as it cools. At first the ridge is a huge bulge on the Earth's surface. Afterwards it is sculptured into shape by water. The Appalachian Mountains are 1,000 miles long, 100 miles wide and 3,000 feet high. The Rocky Mountains and the Andes together are 10,000 miles long, 500 to 1,000 miles wide and 10,000 to 20,000 feet high Water has carved them into shape.

All Nova Scotia and New England and the very places where the cities of New York, Philadelphia, Baltimore, Washington and Richmond now stand were once covered with mountains as high as the Alps. Water has worn them away.

The Pressure of the Rocks within the Earth.—Imagine the pressure on the bottom bricks of a brick wall 100 feet high. If the wall were 1,000 feet high the bottom bricks would be ground to powder. The rocks fifty miles deep in the Earth would be ground to powder, too, if each piece of rock were not packed on every side—from below as well as from above. If a crack opens near such a piece, the rock will *flow* through the crack just as tar would. The motion will produce great heat, just as drawing a rough file over iron produces heat.

The least weakness in the Earth's crust, anywhere, produces crumpling. It may build mountains.

Take a piece of putty or dough and push it sidewise from both sides. The center will rise into the shape of a mountain. (Try it.)

The amount of rock removed by water is enormous, as Fig. 154 shows. Probably five miles of rock has been washed off the top of the Appalachian Mountains and more than a mile from above the present Rocky Mountains. The shapes of the mountains as we see them now are entirely due to water.

Fauna and Flora.—The animals that inhabit any country or region are called its *fauna*; the trees and plants, its *flora*. Some animals (the alligator for instance) are only found in certain regions.

FIG. 155. Characteristic flora and fauna of Australia. The moment you see this picture you know that it was taken in Australia and nowhere else.

Some plants live only in certain places. There were no mammoths or camels in America when Columbus landed (1492), but there used to be thousands of them. Their skeletons are still found by scores.

Fossils.—The stratified rocks were formed in seas, lakes, and in the deltas of rivers. Shells, bones, skeletons, leaves, plants, logs and the like were buried in these layers millions of years ago and some of them have been preserved. They have been turned into stone. We know something about the fauna and flora of past times by the fossils that have been found. We know that the Kangaroo, to-day, belongs to Australia. In the same way we can associate certain fossils with certain layers of rock—with certain ages. If you find a certain kind of fossil fish in Iceland and another of the same kind in Norway you know that the two rocks containing the fish are of about the same age, because that fish lived at one period of the Earth's history and at no other. The animals and plants that first appeared on the Earth are buried in the deepest layers.

The Unstratified Rocks.—Granites and lavas that are not stratified form the greater part of all the mass of the globe. They lie deep down, and we only see them when the rocks above them have been worn away by water or when they have (like lavas) been pushed up by pressure from below.

Volcanoes.—Volcanoes are mountains built up by lava flowing out from the hot interior of the Earth. The lava is forced upwards by pressures in the Earth's interior. Lava is melted rock. Enormous quantities of it flow from some volcanoes. The whole of the Hawaiian Islands have been built from lava flows. In the northwestern parts of the United States (Washington, Idaho) there are lava fields that cover 200,000 square miles, and they are sometimes 3,000 to 4,000 feet thick. Arizona has a lava field covering 25,000 square miles. These immense sheets of lava were not sent out all at one time, but the lava flows were spread over millions of years. Mt. Etna is 11,000 feet high and 90 miles in circumference and is all solid lava; the Hawaiian volcanoes are much larger. There are hundreds of active volcanoes now; and thousands of extinct volcanoes.

The surface of the Moon (see Figs. 22 and 26) is covered with extinct volcanoes.

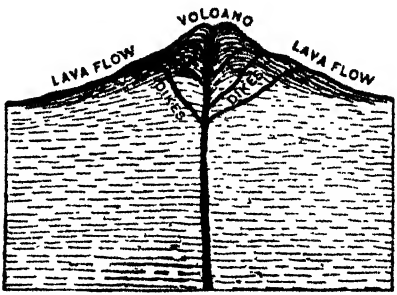


FIG. 156. Lava (colored black in the picture) flows from a hot reservoir deep down in the Earth to the surface and flows out. It builds up first a hill and then a mountain.

Vesuvius.—One of the most famous active volcanoes is Vesuvius, near Naples, in Italy. In the

the year A. D. 79 a terrific eruption took place which buried the cities of Herculaneum and Pompeii[1] under heaps of volcanic mud and ashes.

FIG. 157. A portion of Pompeii with the heaps of ashes removed. Many of the houses remain just as they were twenty centuries ago. Mt. Vesuvius shows in the distance.

Imagine New York to be buried under heaps of ashes and to remain buried for twenty centuries! The people who would uncover it in the year A. D. 4000 would know exactly how we lived, how our houses were built, what clothes we wore, how we worked and how we amused ourselves. The inhabitants of Pompeii rushed from their houses leaving everything behind them. A few who returned to save their money or jewels perished. Everything remained untouched. When the city was uncovered after all those centuries the very bread was found on the counter in the baker's shop! A notice was found *Cave Canem* (Beware of the Dog!) to warn passers-by of a fierce watch-dog.

[1] Pronounced pom-pā'yē.

Volcanoes send out gas, flame, steam, mud, ashes, hot stones and floods of melted lava, or sometimes of hot mud

The steam causes violent explosions and sometimes tears the mountains to pieces as at Krakatoa, near Java, in 1883, and in Martinique in 1901.

The volcano of Cotopaxi is known to have thrown a rock nine feet square and thirty feet long nine miles away. Instances of the sort give some idea of the immense energy of the explosions.

Earthquakes. — If the underground rocks are moved at all a shock is sent in every direction. Ten million tons of rock moving a hundredth of an inch will make a heavy shock, and if the movement is not too deep underground we shall feel the shock at the surface. The earthquake at Charleston, in 1886, threw down hundreds of houses, opened great cracks in the ground, made new ponds and lakes, and was felt all the way from Wisconsin to Cuba. At the Lisbon earthquake (1755) forty thousand persons perished—many of them by great waves that rolled in from the sea when the level of the ocean-floor was changed. There are earthquakes during every volcanic eruption. It is the earthquakes of millions of years that have crumpled the crust of the Earth.

The Age of the Earth.—No one can tell the age of the Earth exactly, but we can form some idea of it. The sedimentary rocks were all formed by soil washed out to sea. The sedimentary rocks are *certainly* 6,000 feet thick (probably they are more; see page 158). Rivers bring soil from the land at the rate of about one foot deep of soil every 5,000 years (see page 141) 6,000 times 5,000 = 30,000,000 years. If the rivers of old time worked no faster than the rivers of our time then the Earth must be *at least* 30,000,000 years old.

Suppose that one of your steps—two feet long—stood for a hundred years and that you start out for a walk. Three steps from your house put a stake in the ground to stand for the landing of the Pilgrims, three hundred years ago nearly (1620); four steps from your house put another stake to stand for the landing of Columbus (1492); at eight steps put a stake to stand for the conquest of England by William the Conqueror (1066); at nineteen steps, a stake to stand for the date of the birth of Christ; at sixty steps, another to stand for the building of the Pyramids in Egypt (about 4,000 B.C.). Nearly all the history we know is represented by sixty of your steps. It would take 15,000 such steps (about 6 miles) to mark off a million years of the Earth's history. You would have to walk *at least* 180 miles to represent the age of the Earth.

If the time during which the Earth has endured is represented by 180 *miles* then the whole known history of mankind is represented by not more than a couple of hundred *feet*.

Geological Ages.—We can tell the age of some rocks by noticing what fossils they contain. First of all, there are many rocks (granites, lavas, etc.) that contain no fossils at all. We can tell nothing about them. They are called rocks of the *Archean* age.

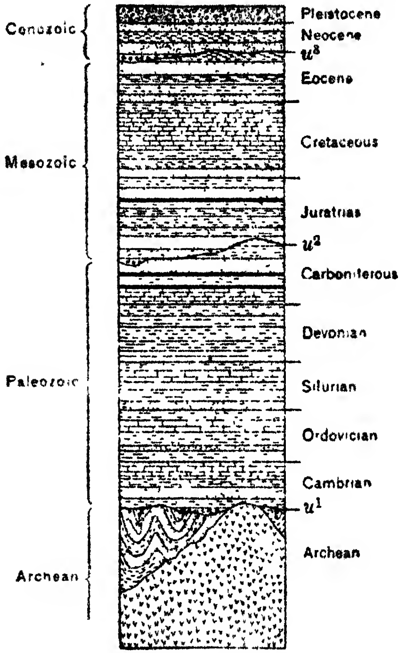


FIG. 158. The succession of the rocks of the Earth's crust. The oldest rocks are at the bottom, the youngest at the top. They were deposited in that order. The *Archean* rocks have no fossils; the *Age of Invertebrates* has few animals with backbones; in the *Age of Reptiles* animals with backbones, especially reptiles, are numerous; in the *Age of Mammals* there are many animals that give suck to their young.

Lying over them are layers of rocks that contain the fossil remains of plants, seaweeds, shellfish, etc.

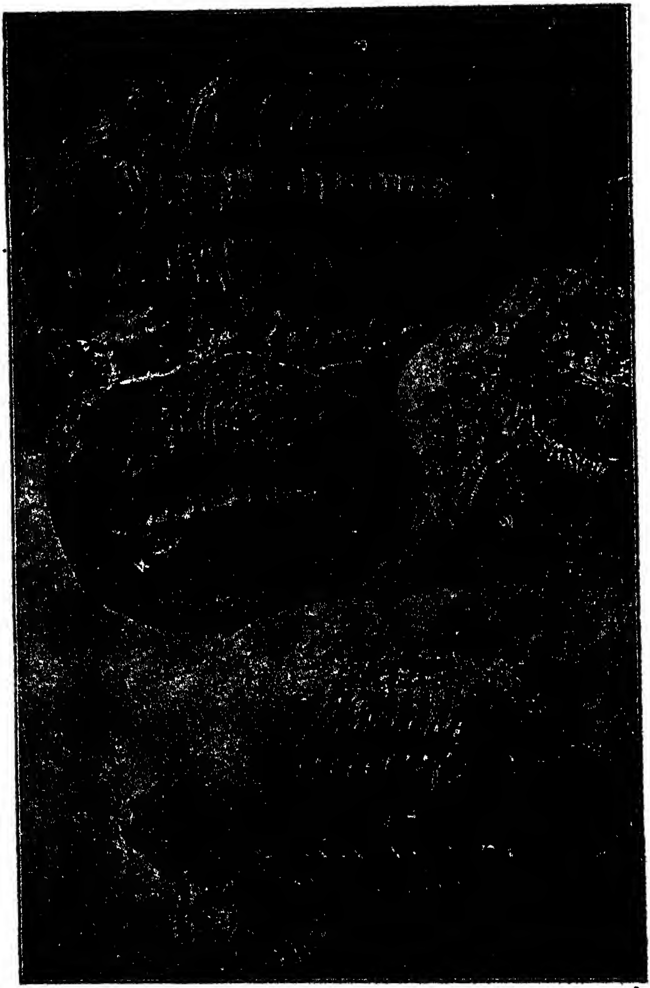


FIG. 159. Some of the fossils of the age of invertebrates—of the age when there were few animals with backbones.

This is the *Age of Invertebrates*—of animals without backbones. There were plenty of fish, though, in this Age. It is also called the *Paleozoic* Age—the age of ancient life, the name means.

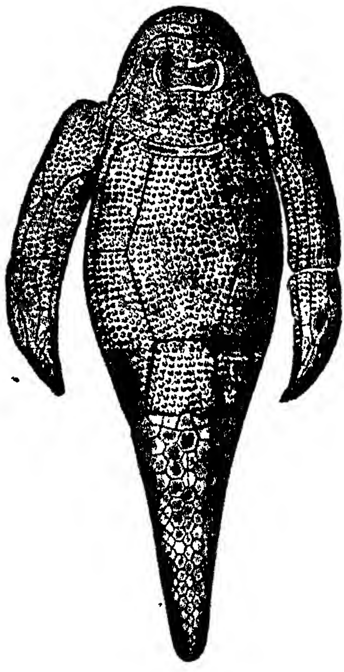


FIG. 160. A fish of the Devonian period. Its body is covered with scales like that of a reptile—of a lizard, for instance.

Lying over these rocks, again, are others, that are not so old; they lie uppermost; they were deposited later. The fossils in these rocks are mostly reptiles—lizards, etc., besides fish, plants, trees.

This is called the *Age of Reptiles*; or the *Mesozoic Age*—the middle age of life. And, lying over these rocks, again, are others younger still, that contain the fossils of animals that give suck to their young — mammals (such as foxes, dogs, wolves, lions, horses, cows, elephants, and man). This is called the *Age of Mammals* — the age in which animals that give suck to their young are common. And these great Ages are divided into shorter periods. The *Carboniferous* period is that in which the coal was formed: the *Glacial period* is that when the Earth's surface was largely covered with glaciers, and there are many others.

Life in the Age of Invertebrates.—What life there may have been before this Age we do not know. The earlier rocks have no fossils. The earliest fossils belong to the age of animals without a backbone and to the seaweeds of those times. There were many corals; an incredible number of shell fish, some of them fifteen feet long; fishes of many kinds, some of them almost like reptiles, and so forth.

The Coal-Period.—The coal beds of the world are immense swamps of ancient times in which the trees have rotted and died. During long ages the trees have been gradually turned into coal.

A thick forest makes about a ton of dead leaves, dead branches and trunks on every acre every year. If you spread this evenly over an acre it makes a layer less than a thousandth of an inch thick. In some coal fields the solid coal is over a hundred *feet* thick, and it must have taken something like a million years (1,200 × 1,000 = 1,200,000) for these beds to be formed.

FIG. 161 A landscape in the coal period. Notice the curious trees, very different from ours. Fossil trees of this kind are found in coal. In fact, coal is nothing but the fossil remains of such trees. Some of the trees were at least 50 feet high and 4 feet in diameter.

Peat-Bogs. — Now-a-days we find in certain countries great marshes or bogs of a thick black mud called *peat.* Ireland has many such bogs — one of them is fifty miles long for instance. In the United States there are many also. The peat is mostly made up of decayed trees and plants (carbon, nitrogen, etc.). Plants and trees drop their leaves every year and finally die themselves, and fall. In wet places peat is formed, often rapidly. Coins left by Roman soldiers 2,000 years ago have been found covered by ten feet of peat bog, so that the peat has increased about a foot every two centuries, in that particular place.

There are many single layers where the coal is 50 feet thick and the thickness of the rocks that contain coal is more than two miles. The ancient swamps were of immense extent. In Pennsylvania, Ohio, Virginia, Tennessee, Georgia and Alabama there are more than 60,000 square miles of coal lands, and in North America alone about 200,000 square miles. These were once swamps.

The climate in those times was very different from now; it was warm and moist everywhere, even in the arctic regions (where coal is often found and where there must have been forests, of course). There were many corals, land and fresh-water shells, and very many insects, such as dragon-flies, spiders, beetles. These insects had organs by which they could make a noise, a note, to call their fellows.

Life in the Age of Reptiles.—Some of the fish of the Age of Invertebrates gradually turned into reptiles—land and sea animals with a backbone—somewhat as a tadpole changes into a frog. That is, the descendants of some of the early fishes became reptiles; the descendants of other fish re-

FIG. 162. Flora and fauna of the Jurassic period. Notice the lizard-like birds with teeth.

mained fish. They breathed through gills and not with lungs. The reptiles lived sometimes on land, sometimes in the sea. After millions of years some of the reptiles grew immensely large as we know by their skeletons found to-day.

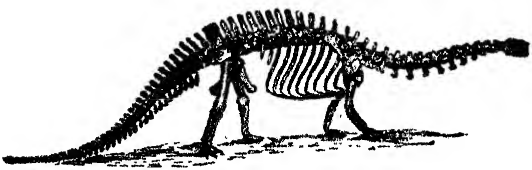


FIG. 163. The skeleton of a Brontosaurus. Some of these huge lizard-like animals were 50 feet long and weighed something like 20 tons. They walked; they did not crawl; and sometimes they stood upright.

Life Since the Age of Coal.—The plants, trees, fish and animals of the Age of Coal and the ages

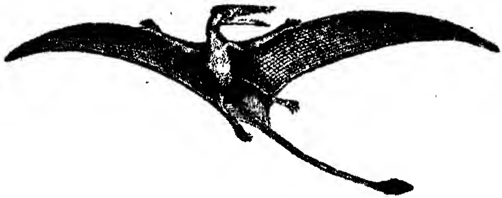


FIG. 164. A flying reptile. Some of these reptiles had a spread of wings as much as twenty feet.

before it were very different indeed from those that we know. But they were the ancestors of our plants and animals. Some fishes gradually lost their armored scales and their descendants became our fish. The flying reptiles were the ancestors of

FIG. 165. A landscape of the Chalk period. The trees are not unlike our redwoods and palms.

our birds. Our horses are the descendants of animals of the same sort that lived in these ancient times. Our oak trees, poplars, willows and so forth, were unknown till the Chalk period, but they are the children of old forms of trees, much changed in the course of millions of years. Great lizard-like animals of past times were the ancestors of our crocodiles and alligators.

Ancestors of the Horse.—The fossil remains of horses that lived millions of years ago have been discovered, and their bones are now in our museums. There was the *Eöhippus*, the first horse, the ancestor of all horses. He was no bigger than a fox, and he had five toes on his front feet instead of one toe (a hoof) as our horses have. This horse lived about 4,000,000 years ago. Next came the *Orohippus* (mountain horse), which was about the same size, and which had four toes on his front feet. Next came the *Mesohippus*, a horse about the size of a sheep, having three toes on his front feet. He lived about 2,000,000 years ago. Then came the *Protohippus*, about the size of a donkey, having three toes, only one of which touched the ground. The others were too high to touch it.

Then, about 1,000,000 years ago, came the *Pliohippus*, a small pony, with hoofs; and finally the horse.

Four million years ago all the horses had five toes and were no larger than foxes. They found good food and grew larger because they found it.

The larger and stronger the horse the more food he could find, the further he could travel to find it. If he lived in stony places, as *Orohippus* did, the horse with the fewest and hardest toes was the most fitted to live in those places. The strongest and biggest horses had the strongest and biggest colts, and they, in their turn had stronger and bigger colts. Finally, in three million years or so, the children of the little *Eohippus* had grown to be real horses. *The fittest survived* and had colts; *the weakest perished* in the struggle for existence.

Natural Selection—The Struggle for Existence. Every animal gets its food and saves its life from enemies by a struggle for existence. The fittest survive; the weaker die. It is the same with plants and trees; with fish and birds. Why, do you suppose, are most wild animals, deer for instance, of the same color on both sides? And why is that color the color of the regions in which the deer live? Because a dun-colored deer is not so easily seen in a desert as a black one. More of the black ones have been killed by lions and tigers; more of the dun-colored have survived. The young deer grow like their parents in color. Deer are the same color on both sides because the deer of different colors are quickest seen and most often killed. Fewer of them live to have young. Lions are the same color on both sides because the lions that were of different colors were more easily seen; they got less food; fewer of them lived to have young. Wild bulls are nearly always of the same color on both sides; farm bulls are often of several colors. It makes no difference in their life on a farm what color they are. But it makes a difference to the wild bulls. Bears that live in forests are brown; polar bears are white to match the snow.

Learn these lines by heart; they were written as a joke, but they are true if they are rightly understood.

The fastest lions caught the most animals,
And the fastest animals got away from the most lions:
So all the slow animals were eaten,
And all the slow lions starved to death!

Heredity: Adaptation.—Young plants or animals are much like their parents. They *inherit* their shape and size from their ancestors. A young tree is always an oak if it grew from an acorn; it never turns out to be a willow or a chestnut. But all the young trees are not equally vigorous. Some of them can stand several dry summers in succession, and some cannot. Trees that can best adapt themselves to their surroundings live the most vigorous lives and have the healthiest acorns. If the climate changes, the weak trees die and the others well adapt themselves to new circumstances. If the climate changes very slowly indeed, the oak tree, in thousands of years may change very much. In California, where there is no winter, the oak trees are evergreen; they do not shed their leaves at all.

Animals change in the same way. Once there were no birds, but there were flying reptiles. Then came a kind of reptile with feathers, and afterwards a bird. Some of the ancient fishes were half reptiles. Some of the great lizards were half whales; others were partly birds, partly mammals.

Every living thing must adapt itself to its surroundings or die. When the surroundings change many animals and plants die, but many others change and become very different from their former selves.

Some kinds of animals and plants (sea-shells and sea-weeds for example) have changed very little in millions of years. Other kinds, trees, horses, men, have changed very much.

Recent Geological Periods.—Any time not more than four or five millions of years ago is recent in Geology. The times that are most interesting to us are the last two or three hundred thousand years. Man appears on the Earth about 200,000 or 300,000 years ago.

If the entire age of the Earth is measured by two hundred *miles* (one of your steps to a century), the time that men have lived on the Earth will be measured by two hundred of your *steps*, the known history of mankind by about thirty steps.

There have been great changes of climate on the Earth in the last million years. Before the Glacial Period Greenland was covered with a rich vegetation like that of our temperate zones. The fossils prove it. The beds of coal found in the Arctic regions prove that the arctic climate was then warm and moist. Fossil trees that need a warm climate (willows and maples) are now found in Greenland under great cliffs of ice. There were formerly rhinoceroses, elephants, lions, tigers and hyenas (animals that live in warm countries) in England. Their bones are still found in caves together with stone arrow-heads made by men—our ancestors.

The Glacial Period.—(See page 147.) For some reason, not well understood, the climate of North America grew colder. Glaciers a mile thick covered Canada and part of the United States as far south as Ohio. At this time our continent was united with Asia near Alaska and perhaps men came to America along that road. The animals of the country were slowly driven southwards by the ice in search of food and warmth. Many trees and plants were killed by the cold and other more hardy plants took their places. Fossils of Arctic plants

FIG. 166. Arctic poppies growing on edge of a snow-bank.

are now found as far south as Pennsylvania. Fossil plants of the temperate zone are found in Old Mexico. The climate again changed, we do not know why, and the glaciers melted after thousands of years and left the country very much as we see it to-day. You can understand the changes that have taken place on our continent as the climate changed, if you will think of what now takes place on a high mountain in the tropics.

Botanical Regions.—A high mountain in Mexico has perpetual snow on its summit. No plants can live there. Then comes a belt of rocks where there are no trees. Below this is a belt where pine trees grow, and then comes a belt of hard-wood trees. Lowest of all is a belt with palm-trees and all kinds of tropical plants. The chief reason for this is, of course, the temperature. Palms can only grow in hot regions. Pine trees can only grow in cold regions. Few plants grow in the snow. If you divide the Earth's surface into zones there are few plants and no trees in the Arctic zone, many pines and hard-wood trees in the Temperature zones; a profusion of palms in the tropics.

Plants are fixed to the soil and cannot travel from place to place as animals do. Plants, then, must stay where the temperature is favorable to them. They cannot live elsewhere. Wild animals like the buffalo used to range over the Western United States from Canada to Texas. But even then they could not live where they found no good

FIG. 167. Zones of Vegetation.

grasses. Animals live in *regions*, too. Each country has its peculiar fauna and flora. Monkeys, armadilloes, llamas now belong to South America; lions, tigers, zebras, hippopotami, etc., to Africa. They live there because the climate is favorable; they find good food. When the climate of England was warm and favorable there were hippopotami in English rivers; lions, tigers and hyenas in English forests. Elephants and mastodons used to live in North America.

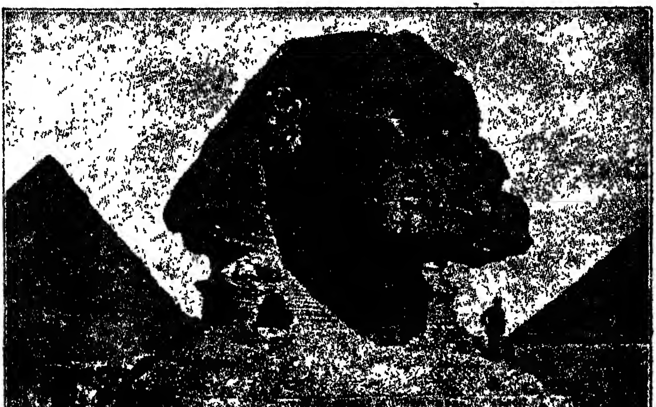


FIG. 168. The pyramids of Egypt and the Sphinx—built six thousand years ago. The great pyramid was 481 feet high.

Prehistoric Man.—There were men in those days too—savages, we should call them—but they are our ancestors. At first they did not know how to make a fire and had weapons of bone or chipped flint (the Stone Age). They were clothed in skins. By and by they learned to weave cloth and to make weapons and tools out of copper (the Bronze Age) and afterwards of iron (the Iron Age). At first they tamed no animal but the dog. By and by they tamed cows, sheep, goats, horses. At first they lived in caves, then they built huts and afterwards houses.

Ten thousand years ago, in Egypt men were cultivating wheat, working in metals, living under a regular government. Six thousand years ago the Egyptian pyramids were built; men had learned to write, to make statues, to live in an orderly way, in peace and comfort.

BOOK VI: ZOÖLOGY.

Zoölogy is the study of animals; Botany is the study of plants (see Book VII). Biology is the study of all living beings, plants and animals alike.

The Study of Zoölogy.—There are millions upon millions of living things on the Earth—fish in the sea, worms in the ground, birds and insects in the air, animals of all sorts on the land. One of the first things to do is to separate all these animals into classes, so as to get those that are alike into one class, and then to study each class thoroughly. For instance, the cats form a class—a large family, as it were. The panthers form another class, the leopards another, the tigers another. After each of these classes has been studied by itself, we must see if there is any likeness between the different classes; how the cats, the leopards and the tigers resemble each other and how they differ.

Kingdom, Class, Order, Family, Genus, Species.—In this way animals are separated into groups and companies. All the animals of one group are like those of the same group and differ, in some way, from the animals in all other groups. Take an Angora cat, for instance. It belongs to

The *Kingdom* of animals,

The *Branch* of vertebrates (animals with backbones),

The *Class* of mammals (animals that suckle their young),

The *Order* of Carnivora (meat-eaters),

The *Family* of Felidæ (the cats, lions, tigers, lynxes, etc., all belong to this family),

The *Genus* Felis (wildcats, cats, but not lynxes, belong to this genus),

The *Species* Domestic Cats (there are several kinds in this species),

The *Variety* Angora (there is only one kind in this variety; but there are other varieties).

A schoolboy—let us call him John Robinson—sometimes addresses a letter to himself this way: Mr. John Robinson, 227 Michigan Avenue, Chicago, Cook County, Illinois, United States, North America, Western Hemisphere, World. The postman can find him in time. The address fully describes him. In the same way the angora cat is fully described by the variety, species, genus, etc., and cannot be *completely* described in fewer words. There are many boys of the *genus* schoolboy, and a number of the *species* Robinson, but not so many of the *variety* John Robinson.

Differences between Plants and Animals.—It is easy to distinguish between the plants and the higher animals. A horse is an animal; an oak-tree is a plant. Most animals can move from place to place, but some animals—corals and sponges, for instance—are fixed to one place; a few plants can move about. Animals can generally see, hear, touch, smell, taste; they digest their food; their blood circulates. Animals usually eat other animals (as the lion does) or they eat plants (as the cow does). Plants usually get their food from the air and from the soil (though there are plants that catch flies and eat them). Animals usually breathe in oxygen and breathe out carbonic acid gas. Plants usually breathe in carbonic acid gas and breathe out oxygen.

Sometimes it is very difficult to tell the lowest kinds of animals from plants. People at the sea-shore press sea-weeds into albums. Most sea-weeds are plants; but nearly all such albums contain certain animals that look almost exactly like real sea-weed.

Fossil Animals.—Beside the millions of animals now living there are millions of fossil animals (and plants). Usually the living animals are somewhat like their fossil ancestors; they belong to the same family, but not to the same species or variety. The living animals fit the present time and the circumstances in which they live. Their fossil ancestors fitted the very different circumstances of geologic ages long ago. The horse to-day has one toe on each foot; the fossil horses had several toes.

Fauna and Flora.—The animals that live in each country are called its fauna—its animals. The animals of the Arctic regions are the Arctic fauna; those of North America are the North American fauna; of the ocean are the ocean fauna and so forth. Each region has a *flora* too—its plants.

THE EIGHT BRANCHES OF THE ANIMAL KINGDOM.

VIII. *Vertebrates* (animals with backbones: Fish, frogs, birds, reptiles, tigers and the like; and men).

VII. Shell-fish and insects (lobsters, crabs, bees, wasps, etc.).

VI. Clams, oysters, snails, etc.

V. Starfish, etc.

IV. Worms (long squirming animals on the land and in the water: some of them live inside other animals).

III. Jelly-fish, etc.

II. Sponges (and other plant-like water-animals that cannot move about).

I. The lowest animals (animals made up of a single cell, and usually only to be seen by a microscope).

All living and fossil animals belong to one of the eight branches of the animal kingdom; and in each branch there are thousands of families, species and varieties. Zoölogy studies all these animals, all these species. In this book we shall only describe a few specimens of each branch, and we shall begin with the simplest of all animals and go on to the highest of all—that is, man.

A spade is a machine; a steam engine is a machine. The steam engine is a higher kind of machine than a spade not because it is more powerful, but because it is more complicated and because it can do very many kinds of work while the spade can only do one kind. The ox is stronger than a man; but a man is higher because he can do many kinds of work while the ox is fitted to do only a few kinds.

Cells.—In the first place it is necessary to say that the bodies of all animals are made up of *cells*, so called. The body of a man, for instance, is made up of thousands and thousands of cells each one of them being a bit of *protoplasm* (something like the white of an egg) and all of them being very small, about $\frac{1}{5000}$ of an inch. When you wound your hand it heals by new cells forming on the wounded places and taking the place of the old ones.

Protoplasm is the glairy mass that makes up each one of the cells of every animal's body. It is a chemical compound of carbon, hydrogen, oxygen and nitrogen. These four things are dead elements and no one of them, by itself, can be alive. When they are combined into protoplasm the combination can be alive. When the body dies it separates into its elements again.

One-celled Animals—the Amœba.—The very simplest of all animals are made up of one and only one cell. They are very small. *Amœba* lives in pools or ditches of water in the ooze or mud at the bottom. If you put some of this mud on a plate of glass under a microscope you will see a very small moving mass that looks like transparent jelly. It is alive. It moves by swelling out on one side and then flowing towards that side somewhat as a drop of honey flows. It feeds on very small plants (*diatoms*) by flowing over and around them — swallowing them, as it were. If you touch it, its body shrinks, which proves that it can feel. It can move. It digests its food, using some of it, rejecting the rest. It grows. It absorbs oxygen, and gives out carbonic acid gas, which is a kind of

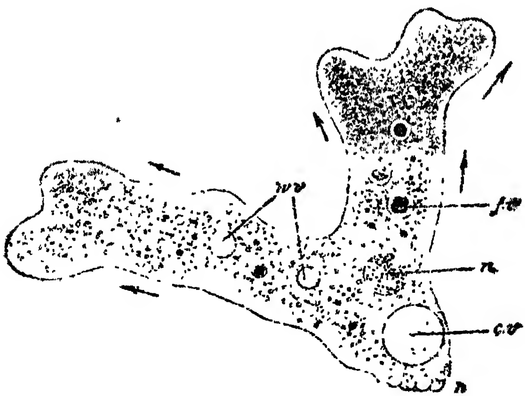


FIG. 169. Amœba, magnified many times. At *n* is the central nucleus of the animal; *w* and *v* are water nuclei; *f v* is one of the food nuclei. The animal flows outward from the center in the direction of the arrows.

Scrape the green growth off the outside of a flower-pot and cover the scrapings with water. In two or three weeks many of these animals will be found in the scrapings. A microscope is needed to see them.

breathing. It often divides into two masses and each of these masses is alive; and then each of these, again, divides — so that a family is born.

The Amœba has no lungs, and yet breathes; no mouth and yet eats; no fixed shape and yet grows; no nerves and yet feels; it is neither male nor female and yet it has a family.

If a common earth worm (a very much higher creature) is cut into two parts each part lives and becomes a perfect worm. Each half of Amœba is a complete animal. *Bacteria* are small plants, that grow, like Amœba, by dividing into two.

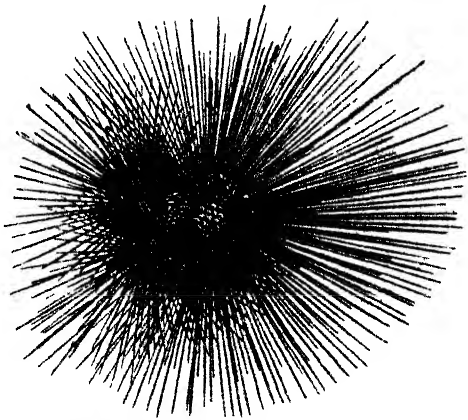


FIG. 170. Globigerina (magnified 100 times). These animals live in the upper layers of the ocean waters by millions. When they die their shells sink to the bottom and are there slowly cemented into limestone rock.

The Ooze or Mud of the Bottom of the Ocean.— Floating on the surface of the ocean there are millions of little creatures that have shells made of lime. Inside the shell is a mass of *protoplasm* (something like the white of egg). The shells are full of little holes and the matter inside them sticks out in spines. All sorts of sea-animals eat them, by thousands, for food. Those that are not eaten die at last and their shells sink slowly to the bottom of the ocean and form the ooze or mud. By and by, in thousands of years, the mud becomes solid chalk. All the great chalk cliffs of England are formed of the shells of such little animals in countless millions.

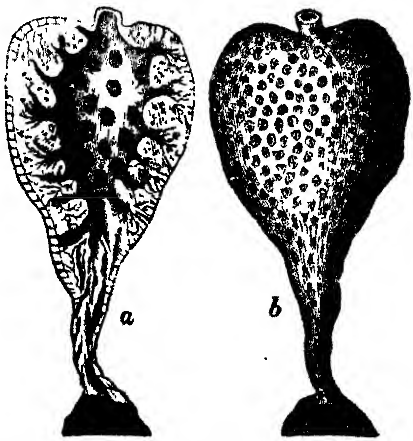


FIG. 171. The right-hand picture shows a sponge with many mouths all over its surface. The left-hand picture shows the same sponge sliced in two. The large central cavity is the stomach.

Many-celled Animals — Sponges. — Sponges are animals made up of cells arranged in layers. The inside of a sponge has many pouches that serve as stomachs and a great many small openings which serve as mouths. The water pours through them and the mouths seize their food (small sea-animals). Inside of the sponge there is a kind of skeleton made of glassy rods and spikes. Young sponges come from eggs formed inside the body of the parent, which is fixed to the rock. The young sponge floats about and, by and by, in its turn, becomes fixed. Some sponges also bud, like flowers, and young sponges are the buds, and are finally separated. You have to remember that even low animals, like sponges, come from eggs. The lowest animals of all divide into parts and each part lives.

Jelly-Fish.—Any one who has been at the seashore has noticed jelly-fish floating about on the

FIG. 172. A jelly-fish seen from the under side—natural size. Some common jelly-fishes grow to be eight or ten inches in diameter.

surface of the water. There are millions of them and they make the food of other sea animals.

They can move about by opening and closing the edge of their flat body as if it were a kind of a fin. Water and a kind of fluid circulate through their veins somewhat as red blood circulates in ours. They have eyes to see, and ears to hear, a stomach, and curious thread-like organs that sting any animal swimming near by. The sting paralyzes what it touches, and that is the way the jelly-fish gets its food. The young of the jelly-fish shown in Fig. 172 are born from eggs.

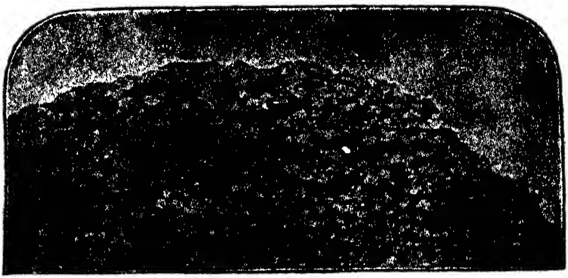


FIG. 173. A colony of live coral animals above a rock formed of the bodies of thousands of dead corals.

Corals are little animals that live in warm sea water near the surface. The skeletons of these little animals are made of carbonate of lime that they extract from the sea water. When they die the skeleton is left and forms a rock. Corals live together in colonies. A coral island is nothing but the skeletons of millions and millions of dead corals, and it is usually surrounded by reefs of corals that are living. Branches of red coral are used for jewelry you know.

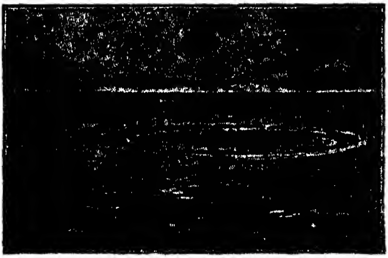


FIG. 174 An island formed entirely of coral rock.

Hydra.—The hydra is a very small water animal found in fresh-water ponds. It has feelers that

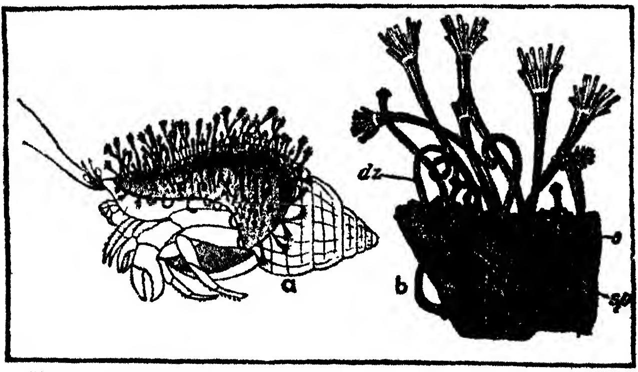


FIG. 175. The left-hand picture shows a colony of hydroids growing on the shell of a hermit-crab. The right-hand picture shows a bit of the colony drawn larger. The hydra forms buds somewhat as plants do. The buds drop off and are small jelly-fish and float away. Some jelly-fishes come from budding; some from eggs.

sting like nettles and paralyze other little animals that it uses for food. Jelly-fishes and coral animals have the same kind of feelers which they use in the same way If a Hydra is cut into slices crosswise, each slice grows into a complete animal; if it is cut into strips lengthwise each strip makes a complete animal.

Worms.—The best way to understand what a worm is like and how he moves is to dig up a few earth-worms and to put them on china plates. In one of the plates put some garden soil and watch the worm as he burrows into it. We think the worm is a very low animal, but it has eyes to see, ears to hear, nerves to feel, a head and a kind of brain in it, a body made up of separate rings, muscles, a skin, a mouth and stomach (or, rather, a gizzard in which the food is ground up) a kind of heart with white blood in it. It can move about on the ground or even climb a vertical wall by using rows of short bristles that are arranged on each side of its body. The earth-worm burrows by swelling out its head till it pushes the dirt away on both sides and also by swallowing some of the dirt and passing it through its body. The thousands of earth-worms in every field do much good by loosening the soil, thus allowing the air and rain to reach the roots of plants. They work the soil over by the finest kind of gardening, and the layer of blackish soil at the top of the ground (you can see it almost everywhere) is their work. Their chief food is half-decayed leaves. They lay eggs from which the young are hatched; although if a worm be cut into two pieces each of the pieces will grow to be a complete worm. They are like the Amœba (page 188) in this, and like the birds and crocodiles in laying eggs. If two worms are each cut in half the tail of one worm can be made to grow on to the head of the other so as to make a new animal.

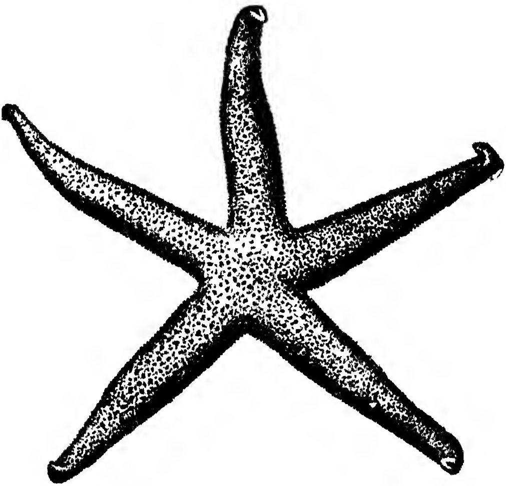


FIG. 176. A starfish. This particular kind is blood-red in color and has a skin like leather. It is about four inches in diameter.

Starfish (Radiates).—Children who live near the seashore can catch a starfish any day—for there are thousands of them—and keep it in salt water for study. These animals are built like a five-pointed star with arms about an inch long. At the end of each arm there is an eye—five eyes in all. The eyes show the arms which way to crawl, and underneath each arm are rows of little suckers by which the crawling is done. The mouth and stomach of the animal are at the center of the star.

There is a ring of nerves around the animal's mouth, other nerves running along each arm, and little nerves running to each sucker. The animal can feel and see, and smell and breathe. Its young are hatched from eggs. Inside of its body are channels through which water and other fluids circulate somewhat as red blood circulates in our own veins.

If one of the arms is broken off it dies—it does not grow into a new animal; but a new arm grows in its place. Injuries like this are quickly made whole again in the lower animals. If your leg were cut off it would never grow again, of course; still less would it grow into another boy. The starfish can replace a lost leg; and a worm cut in two grows into two separate worms. The starfishes eat mussels and oysters. When an oyster is open (trying to get *its* food) the starfish places part of its body in the opening and sucks the soft part of the oyster up into its own mouth.

Oysters have two shells joined by a hinge and shut by a muscle. (Look at the two shells of an oyster and see how the hinge is arranged. The muscle is fastened where the purple spot shows on the inside of the shell.) The gristly part of the body of the oyster is the muscle itself and the soft greenish part is the oyster's liver. The layers around part of the body are the oyster's gills by which it breathes. Oysters have a heart somewhat like our hearts and a set of veins and arteries, but no *red* blood, of course.

The young of clams, mussels and oysters come from eggs; and a single oyster may produce a million young. The food of oysters is made up of little sea-animals floating in the water in the oyster's open shell; but they can be fattened on corn-meal, too.

Pearls are formed inside the oyster round some little grain of sand, somewhat as our own flesh might grow around a bullet.

Mother-of-Pearl. –The oyster builds its own shell of layers upon layers of the very same stuff of which pearls are made, adding to them from the inside.

These thin layers one upon another make fine ridges like parallel lines and light shining on the ridges is scattered so as to make the rainbow colors. The colors are due to the ridges, as you can prove by taking an impression of the inside of the shell in wax and noticing that the little ridges in the wax give the same rainbow colors.

The Lobster. — The group of animals to which the lobster, the crab, and all insects belong, has the two sides of the body alike. The legs, jaws and so forth are arranged in pairs. The earthworm is made up of a number of rings, one ring like another. The arrangement of the starfish is five-fold; it has five arms. Man and the higher animals are built so that the right-hand and left-hand halves of their bodies are alike.

The lobster has a heart which pumps its colorless blood through arteries. It breathes through gills near the roots of its eight walking legs. It has a liver, a stomach, muscles, eyes, ears, feelers. It can smell. It has a memory, too, for lobsters that have been caught, marked, and then set free again, have found their way back to their old home, several miles away. The lobster sometimes has as many as 100,000 eggs. The natural color of its shell is dark green which becomes bright red when the animal is boiled for food. Once a year the lobster *moults* that is, it splits and discards its old shell and appears in a larger and softer shell that has been formed inside of the old one. The new shell soon hardens and the animal lives inside of it for another year.

FIG. 177. The lady-crab (one-third of natural size). This is one of the swimming crabs and is good to eat.

Crabs.—The hermit-crab has no shell of its own but selects an empty sea-shell to live in, backs into it and carries its house about until the house becomes too small, when it chooses another and larger shell. (See the picture, Fig. 175.)

Insects. — Insects have the head well separated from the body. Some insects (the grasshopper for instance) get their food by biting it with their jaws; others (the bee and butterfly) suck their food up through a tube.

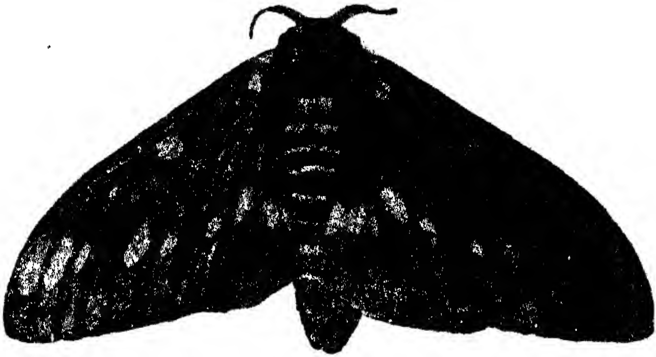


FIG. 178. The Regal Moth, natural size. It has olive and red wings with yellow spots.

Insects lay eggs from which the young are hatched, but the egg does not hatch into a complete insect. The butterfly's egg first hatches into a *larva* (the caterpillar for instance); then the *larva* turns into a *pupa* (the caterpillar turns into a chrysalis); and finally the *pupa* turns into the insect (the chrysalis turns into a butterfly).

FIG. 179. Larva of the Regal Moth, one-half of the natural size. Its head is to the left hand.

FIG. 180. The male and female moths of the Tent Caterpillar (the female is the larger). These are very destructive to apple trees.

FIG. 181 Masses of the Eggs of the Tent Moth Caterpillar on the branch of a tree The eggs stay on the tree all winter and hatch out in the spring.

FIG. 182. Nest of the larvæ of the Tent Moth Caterpillar It looks like a kind of spider web. The larvæ live on it in a colony and each one of them turns into a moth.

Pick up three or four of the common red and black hairy caterpillars and put them in a box with some fresh clover leaves. Before very long you will find one or more hairy cocoons. The caterpillar inside of this in the form of a smooth brown *pupa* or *chrysalis*. A week or so after the cocoon is formed it splits open at one end, and a winged moth—the Isabella Tiger Moth—comes out and flies away.

Intelligence of Insects: Ants.—Insects have a brain and are able to do quite wonderful things. The brain of the ant is proportionally larger than that of any other insect. Some of the ants (the rust-red ants that live under large flat stones) make slaves of other ants (black ants). They go out in war-parties, capture the black ants and make them work. The black ants feed their masters and build their nests for them. The agricultural ant of Texas clears a space about its ant-hill and allows only one kind of grass to grow there. It harvests the ripe grass seeds and stores them away for winter food. From time to time the seeds are brought out and dried in the sun to prevent their sprouting. The army ants of South Africa live by hunting and migrate from place to place in search of food. The young ants are carried by the older ones. When the army of ants arrives at any place every living thing tries to escape. The ants devour all the other insects, spiders, birds, rats and so forth. When they come to a house the men leave it and in a few hours everything that is edible is eaten. If these ants could make a plan and remember it they could drive all the inhabitants of a country out of it. The leaf-cutting ants of South America work in gangs. One gang goes up the tree and cuts the leaves into pieces of a convenient size; another gang picks up the pieces that fall to the ground and carries them to the door of the ant-hill. Another gang stores the leaves away. Some ants keep and feed the *aphis* insects as we keep and feed cows and regularly "milk" them for honey.

Ants Have a Kind of Language.—Two ants continually stroke each other with their *antennæ* (feelers) and can tell each other where to find food; that an enemy is coming, and so forth. They are fond of their comrades, remember them, and show signs of joy when they return after an absence of more than a year.

Bees.—The bumble bees build nests in the ground. All of them except the queen-bee die every autumn. In the spring each queen-bee lays eggs that develop into worker-bees. When the worker-bees are grown they gather and store food in the nest. They live together all summer and only the queen-bees survive the winter. Our honey bees feed their young while they are unable to feed themselves. When a colony of honey-bees gets too large a number of the workers "swarm" and emigrate to a new nest taking a queen bee with them to lay eggs.

FIG. 184. A swarm of bees.

Honey is derived from the nectar of flowers and is stored into the honeycomb which is made of beeswax.

Intelligence of Honey-Bees.—A hive of bees is a city of 80,000 inhabitants and the wax houses of the city—the cells of the honey-comb—have all been built by the swarm. The city has its laws and its customs, its queen, its royal family, its workers. Its people do different kinds of work—some make wax, some make the wax into cells, some form the cells into the correct shape, some gather honey from the flowers to serve as a store of food for the coming winter, some gather pollen to feed the young bees. Others go out early in the morning and return to tell the hive where the best flowers are, others keep the hive clean, others guard the door, others feed the young and the queen. There are more than 60,000 separate cells in a full hive. The wonderful thing about these cells is their shape. Look at a honey-comb and you will see that each cell has the shape of a six-sided lead pencil with a bluntly-pointed end.

Mathematicians can solve by mathematics much too hard for you to understand now a problem like this one: What is the shape of a cell that shall have the greatest possible contents and at the same time the smallest possible surface? You can see for yourself that it cannot be a sphere, it cannot be a cube. It is in fact *exactly* the shape of a bee's cell—a six-sided prism with blunted ends. The bee has solved this problem all by itself—not by mathematics but by practice.

In these cells honey is stored and the queen bee lays the eggs from which new swarms are to be born. When the city gets too full, and after a new queen bee has been born, the old queen leads more than half of the inhabitants away in a flight that lasts until they find a new place to live—usually a new hive that the bee-keeper provides for them—and a new city is built in the new hive.

Before they leave the old hive they have made about 120 pounds of honey, that is, more than [illegible] times the weight of the bees who made it (just as if a city of 80,000 men should make 60,000 tons of provisions). All of this they leave behind them to keep the old city supplied, and industriously make 120 more pounds for the new city they have founded. And so each hive goes on making new hives year after year. Each one of the new hives is governed like a city—has its queen, its royal family, its drones or male bees (who do not work), its workers (who are female bees, but who lay no eggs—all the eggs being laid by the queen). If too many queen bees are born, the workers kill the useless queens. If all the queens are dead and there is no queen to lay eggs for the new city, the workers feed one of the very young bees on a special kind of food that makes the young bee turn into a queen. If it had not been so fed, it would have grown up to be a mere worker.

If you were up above one of our great cities looking down on it and trying to find out what all its men and women were doing you would by and by discover that each one was trying to be as happy as possible for himself. Each person is usually trying to be happy *now*, this instant. If you look in the same way at a hive of bees you will find that each bee is working so that the new hive that is going to swarm off by and by shall be as happy as possible *by and by*. Most men work for the present time; most bees seem to work for the future.

Spiders.—The webs of spiders are beautiful pieces of work and show great intelligence. Some spiders make nests in the

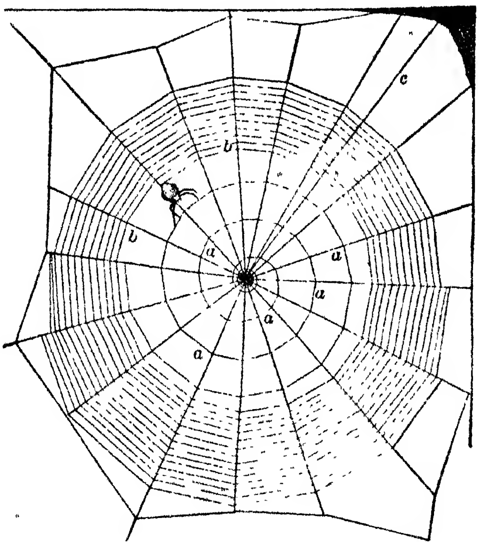


FIG. 184. One kind of spider spinning its web.

ground and close them with a trap door on a hinge. The door is covered with dirt and looks exactly like the ground when it is shut, and this makes it hard for the spider's enemies to find the nest. When an enemy does find it and tries to open the door the spider inside holds it shut with all his force.

Insects are very strong. A fly's wing vibrates 600 times in a second. A flea can jump much further in proportion to its size than any other animal--much further in proportion than even the kangaroo. A bee can pull twenty times its own weight, while a horse can only move about six-sevenths of its own weight.

Insects are both useful and harmful to plants. They are useful in carrying the pollen of one flower to other flowers so that the other flowers can be fertilized. They are harmful too. In four years the Rocky Mountain locusts as they moved eastward did $200,000,000 worth of damage by spoiling the crops in Dakota, etc.

Beetles and other insects are useful to man by eating up or burying offal. Insects are often harmful to man, too. House flies carry the germs that produce typhoid fever. Mosquitoes carry yellow fever germs. The large white ants of the tropics destroy the timbers of houses by eating the fiber of the wood.

Vertebrates are animals with backbones which form part of bony skeletons. They never have more than two pairs of limbs---either two arms and two legs, like men, or four legs like horses. They have a brain-box, or skull; and the mouth, two eyes and two ears are in the skull. All vertebrate animals (fish, frogs, reptiles, birds and mammals—those that suckle their young) have a heart, and birds and mammals have red blood. The fish and the tadpoles breathe by gills, but all the rest have lungs.

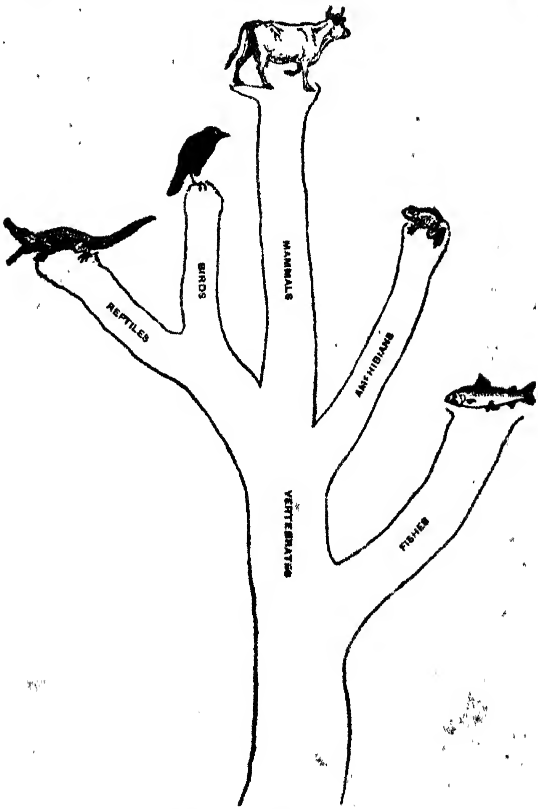


FIG. 185. The vertebrate animals succeed the invertebrates (animals with no backbone). Animals with backbones spread into five branches.

Fishes are cold-blooded animals that live in the water. They are usually covered with scales. They breathe through gills. Their fins are the beginnings of limbs.

Amphibians (frogs and the like) are born from eggs, become a complete animal of one sort (a tadpole, for instance), and then change into a complete animal of another sort (a frog, for instance). The last sort always has legs. Amphibians live in the water and also on land. They are half way between fishes and reptiles.

Reptiles are cold-blooded animals either with shells (turtles and the like), or with skins (snakes, crocodiles). Some live on land, some in the water.

Birds are warm-blooded, air-breathing animals, with feathers.

Mammals are warm-blooded and air-breathing animals. The young are born alive and are suckled by the mother. Whales, for instance, are mammals, not fish.

In what follows we shall speak of some animals of each sort.

Fishes.—The codfish lives in the North Atlantic Ocean, especially on the Grand Banks. The female codfish produces eight or nine million eggs every year. The eggs float on the surface of the water. The mother pays no attention to them and in about twenty days they develop into young fish. Some fishes have a pouch in which they carry the eggs and young fish about till the young are large enough to take care of themselves.

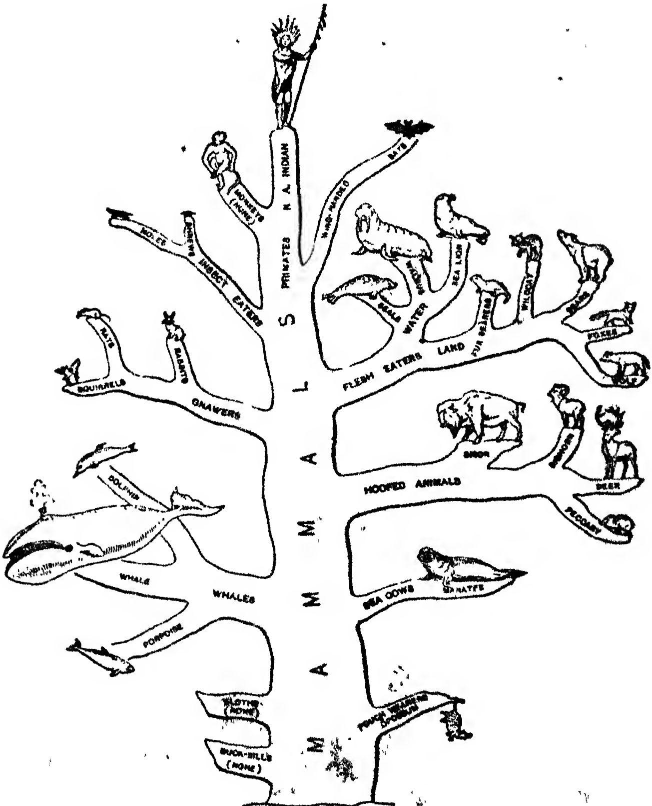


FIG. 186. The Mammals of North America—the highest towards the top. This picture fits at the very top of Fig. 185.

The Dace, a small fresh-water fish, lays its eggs in a running brook, then covers them with a lot of pebbles, then lays more eggs and brings more pebbles, and so on till a little heap of pebbles is formed, in which the young fish are hatched.

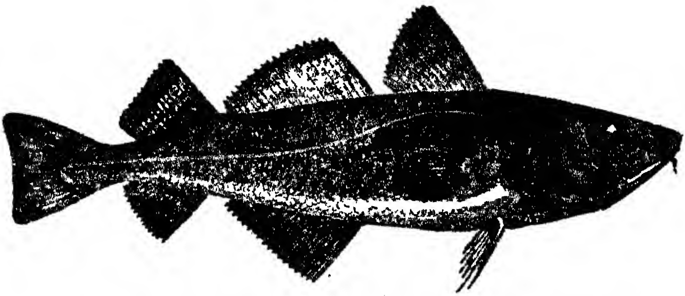


FIG. 187. The Codfish. The real fish is about seven times as long as the picture.

Some fish can fly; their fins are like wings and they make long leaps out of the water and back again. A few fish make sounds to call each other. Most fish have eyes, but those in the Mammoth Cave in Kentucky are blind. Eyes are of no use in the dark, and these fish, whose ancestors could see, have lost the use of their eyes, just as the horse has lost the toes which are of no use to him.

Some fish (the torpedo, the electric eel) have an electric apparatus in their body so that they can give an electric shock to anything that touches them. A fish in the East Indies sometimes travels over land from one pond to another, and is even said to climb trees by means of its spiny fins.

Fish show fear, anger, affection, parental feeling, jealousy, playfulness and curiosity; some of them can be tamed.

FIG. 188. Sticklebacks. The male fish (the upper one in the picture) builds the nest under water. Several females lay their eggs in it and then the male guards the nest to keep enemies away till the young hatch out.

Frogs are born from eggs. The eggs become tadpoles, that is, *fish;* they breathe through gills, live in the water, and have tails. The tadpoles develop into frogs, which live both on land and in the water (*amphibians*) breathe with lungs, and have no tails. Some toads live in trees and their

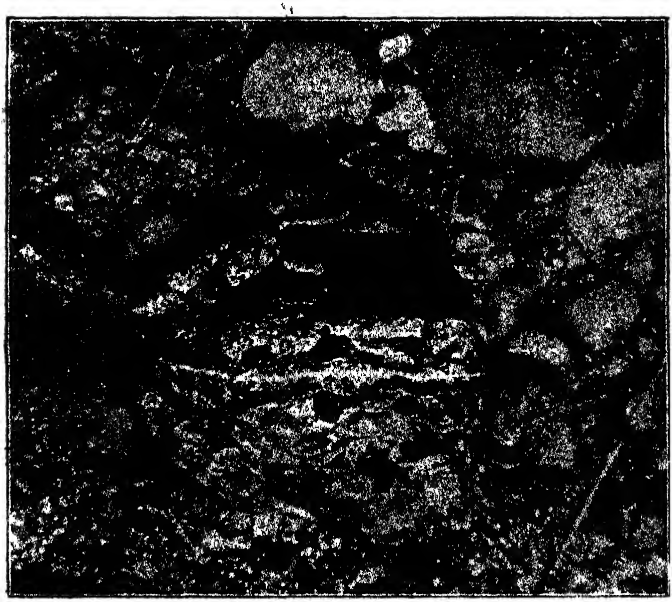


FIG. 189. The Toad: notice how well his color and spots match the color and spots of the ground. The toads that do not match the ground are seen and eaten by their enemies (snakes, birds). Those that do match it live and have young which resemble their parents.

skins change in color to match the green leaves or the gray bark. They escape their enemies in this way.

among plants, like the rat among mammals. It fits the conditions in which it lives; it survives because it is the fittest to survive in those conditions.

A female sparrow has five or six broods each year with four to six young in each brood. If we suppose that twenty-four young sparrows are produced each year, that the young sparrows breed when they are a year old, and that all live—and if all this keeps on for ten years—then one pair of sparrows will produce 138,000,000,000 young ones in ten years! Of course many sparrows are killed, and many die of disease, and some do not have twenty-four young in a year. But the increase is enormous.

Fig. 195. Blue Jay: It belongs to the same family as the crow.

Nests.—Most birds build nests, and sometimes show the greatest skill and patience in building. The tailor-bird sews leaves together with a cotton thread that it makes, and pierces the necessary holes in the leaves with its bill. Some observers say that it makes a kind of a knot in the end of the thread. The cuckoo lays its eggs in the nests of other birds and allows them to be hatched there to save itself the trouble.

FIG. 196. The Sharp-shinned Hawk. Its food is poultry and other birds. Hawks and English sparrows are the two birds that can best be spared. No other birds should be killed.

Female birds usually sit on the eggs and hatch them and male birds usually feed the female and the young. The male ostrich, however, sits on the nest.

Migration of Birds.—Some birds live in the same region all the year round. Most birds, however, migrate (travel) from northern regions to southern in the autumn and back again in the spring. The journey is made in search of food and of warm weather.

FIG. 197. Ruby-throated Humming Birds. They feed on insects and on the nectar of flowers. They build their nests in trees and lay only two white eggs.

Intelligence of Birds.—Gulls and crows open shellfish by dropping them on rocks from high up in the air. Woodpeckers store acorns for winter use. They feed on the grubs fattened by the acorns. Turkey-buzzards tell each other where food is by a high flight into the air which calls other buzzards from a distance. The Frigate Bird will not fish for itself but it follows the Booby-bird and takes the fish that it has caught. The nests of birds are constructed with great intelligence and are often changed in form when new circumstances arise.

Mammals.—The young of mammals are born alive, and are suckled with milk by the mother. Opossums and kangaroos carry the young in a pouch till they can take care of themselves. Mammals have four limbs whose bones are alike. Seals and whales have fins and flippers, dogs and cats four legs, monkeys and man two arms and two legs. All are mammals. Man is the only animal who habitually walks upright and has his arms free.

Horns.—Deer, rhinoceroses, etc., have horns. Deer shed their horns every year. Most mammals do not.

Many mammals have good voices: the gibbon ape can sing eight notes—an octave—correctly. Their voices are used to call their mates, to give alarms, etc. Many animals (the bear for instance) *hibernate*—that is sleep—for a large part of the winter. Most wild animals have a color to match the landscape they live in (see page 175). Arctic animals are usually white. A red polar bear would starve. Why?

BOOK VII: BOTANY.

BOTANY is the science that tells about plants—about vegetables, shrubs, trees.[1] Suppose you see a cherry tree in full blossom. You know that, by and by, it will bear fruit. It will bear cherries—not peaches, not apples. The tree will grow larger, too, as years go on. Botany teaches us how the roots of the tree find food in the soil, and how the food is carried through the stem to all parts of the tree to keep them alive and growing. It tells what the leaves are and what work they do; what the flowers are for and how the fruit comes; why the leaves fall off in the winter when the tree goes to sleep, as it were; how the whole tree wakes up in the spring-time.

To understand all this we must begin at the beginning and learn one thing at a time. And the beginning of plants, like the beginning of animals, is in small parts called *cells*.

Cells.—All parts of plants are made up of very small cells, or cavities; filled up with living vegetable protoplasm.

[1] A tree is a plant; a shrub is a plant; a vegetable is a plant. When we say "plants" we mean all kinds of plants—trees as well as shrubs and grasses."

You have seen a honey comb? It is full of large cavities bounded by walls. Every part of every plant — the stem, the leaves, the fruit—is made up of very small cells, and each cell is filled, usually, with vegetable protoplasm, somewhat as the cells of the honeycomb are filled with honey.

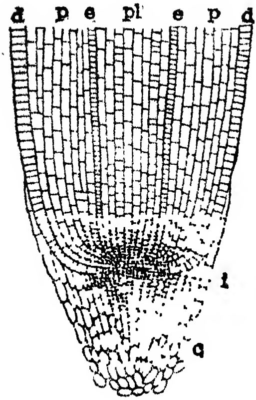


FIG. 209. The growing point of a root of Indian corn (maize) sliced up and down. It is made up of cells. The cells are huddled together in the *growing point* (*i*) where the root is most alive; the very end of the root is protected by a hard cap, the *root cap* (*c*) which bores into the ground like a gimlet; the whole of the root is made up of a tissue of cells, and is covered by a *skin* (*d*, *d*).

If you take the petal of a flower, or a thin transparent bit of seaweed and hold it up between your eye and the light, you can often see little separate cells that make up the tissue—the woven web of the petal or the seaweed. (Try it.)

Or, you can take the delicate rootlet of any seedling plant, cut it into thin slices, and then examine the slices with a magnifying glass or with a microscope. (Try it.)

Every part of a plant or tree is made up of such separate cells. They are usually separated by walls. If you cut a grape into two parts all the liquid inside of it does not escape because most of it is kept in place by the walls of the little cells that have not been cut.

The Cells Contain Protoplasm that is Alive.— No one knows exactly what *life* is; but a plant that is growing is certainly alive. Each cell of such a plant contains a slimy kind of matter (protoplasm) not so very different from the animal called Amœba. (See page 188.)

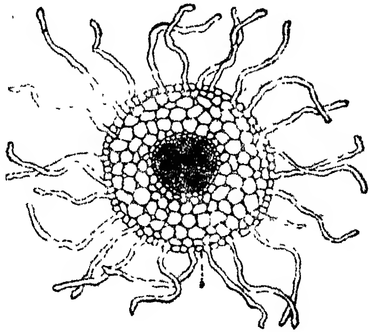


FIG. 210. View of a slice of the root of a plant cut crosswise. It is very much magnified so as to show the cells. The hairs on the root stream out in all directions.

The Amœba sometimes divides into two pa and each part becomes a separate animal. In the same way the cell of a plant often divides into two parts and each part becomes a perfect cell. Plants grow in this way. Where one cell was, you later on find two, then four, then eight, and so on.

Through canals running lengthwise of the cell the protoplasm of one cell is connected with the protoplasm of others on all sides of it. Sometimes the cell-walls become like cork and make the bark of trees. Sometimes the cell-walls become like wood and make the stem. Sometimes the walls become like mucilage, as in the seeds of a quince. Remember that the cells are very small indeed. The largest are about a thirtieth of an inch in diameter; the smallest are less than a thousandth of an inch. There would be 1,000,000,000 of these smallest cells in a cubic inch.

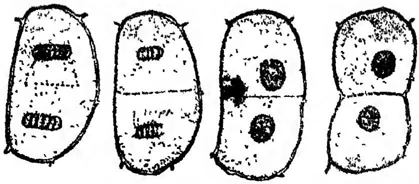


FIG. 211. Four steps in the division of a cell. The left-hand picture shows the mother-cell, very much magnified. There are two nuclei in it, like two yolks in an egg. In the next picture, which was taken a little later in time, a little wall is beginning to grow across the cell. In the third picture the wall has spread all across and has grown thicker. In the last picture there are shown two daughter-cells. By and by each of these will divide and grow, too. In this way each mother-cell will become the parent of hundreds of daughter-cells. The plant grows by the multiplication of its cells.

A plant is made up of thousands of cells just as a wall is made of thousands of bricks, only the cells of growing plants usually have empty spaces between them. In a fine spring day some plants grow three or four inches in length. Millions of new cells must be formed, then, in twenty-four hours. The cells form the *tissues* of the plant; wood-tissue, skin-tissue and so forth.

Color of Plants — Chlorophyll. — The walls of very young cells are usually transparent and colorless. When a plant is growing in the sunlight the cell-walls are stained with a green stain called *chlorophyll.*

Sunlight, acting on the protoplasm of the cell, makes a green coloring stain somewhat as sunlight acting on a photographic plate makes a dark stain.

When an onion grows in a dark cellar its shoots have a sickly pale yellow color. Bring it out into the light and in a short while they will become green. (Try it, if you can.)

Herbs, Shrubs and Trees.—*Herbs* are soft plants with very little wood in their stems (the catnip, for example). *Shrubs* are plants with woody stems that do not grow above twenty or thirty feet high. Currant bushes are shrubs, and so are lilacs. *Trees* are woody plants taller than shrubs.

Annuals, Biennials, Perennials.—All shrubs and trees are perennials; they live on year after year. Some herbs are annuals (the morning-glory, maize, oats, etc., for example). They grow from the seed, blossom, and die all in the same season. Plants of

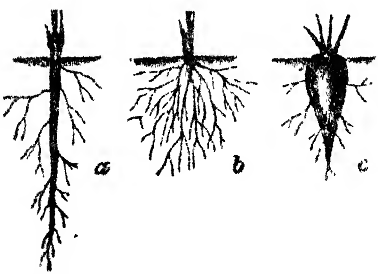


FIG. 212. Different kinds of roots. (*a*) the tap root of a plant (like the young oak tree); (*b*) a root made up of fibers, with no tap-root (like the roots of grass or of the Dahlia); (*c*) a thick tap-root (like the carrot root).

this kind have fibrous roots. Some herbs are biennials—they live for two seasons (turnips, carrots, beets, etc., for instance). They do not blossom at all in the first season but grow leaves and a thick root. The second season they bear flowers and form seeds and then die. Some herbs are also perennials (the peony, dahlia, sweet potato, the iris, etc.).

FIG. 213. A large tree with its roots. They spread out to get food from the soil and to hold up the tree. You see that a good part of the tree is under ground.

The Roots of Plants.—Generally the root strikes downward from the seed into the ground. Its business is to hold the plant up and to get the necessary food and water from the soil. The larger and heavier the plant the firmer its roots must be fixed in the ground. The main body of the root is covered with many fine branches—*root-hairs*—little tubes whose business is to suck water up into the stem and to give it to the leaves. The more leaves there are on a tree the more water they need, and therefore the greater the number of the root-hairs.

Plant a common bean and wait till it has grown a few leaves. Then carefully lift the plant with the soil round its roots and wash away the soil in a wash-basin. Hold the roots up against the light and you can see the fine root-hairs growing from the roots. Each root-hair is a little tube that sucks water up from the soil to feed the plant.

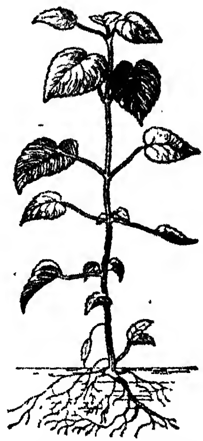


FIG. 214. A plant with a fibrous root. It has no tap-root and it dies every winter, and is therefore called an *annual*—it lives only a year.

Work of Roots.—The water and some of the solid parts of the soil are sucked in by the root-hairs and passed to the interior of the root, from the root to the stem, from the stem to the branches, and from the branches to the leaves, flowers or fruit. The food of the plant comes from the soil; it is turned into sap and circulates in the plant somewhat as blood circulates in your veins. A tree without sap is dead. No matter how a tree is planted its roots will (generally) grow downward, and its stem upward, even in the dark.

FIG. 215. How water rises from the roots of plants (by *root-pressure* as it is called). A footrule is laid along the glass tube to measure the height of water in the glass tube.

Roots grow downward, naturally; stems grow upward, naturally. Why? No one can give a reason in words any more than one can say why young ducks naturally take to the water and why young chickens do not.

Here is an experiment that you can try. Take a strong healthy plant that is growing in a flower pot and cut it off just above the soil. A strong shoot of a grape-vine is a good one to try. Slip a short piece of rubber tubing over the top of the cut off stem. Into the upper end of the tubing slip a small glass tube of about the same size as the stem. Pour in a little water, and notice how the water rises because of the pressure from below. It rises in the glass tube now, just

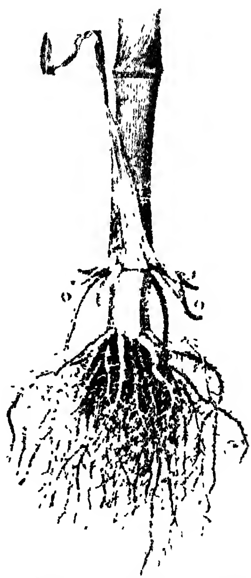


FIG. 216. The roots of Indian corn (maize).

as it rose, before, in the stem of the plant. Some of the solid elements of the soil are dissolved in the water and rise along with it: and it is in this way that the plant gets its food.

Plant Food from the Soil.—The plant gets from the soil carbon, oxygen, nitrogen, hydrogen, potassium, calcium, magnesium, phosphorus, sulphur, iron and chlorine not as elements, but in chemical compounds.

FIG. 218. The Strawberry Vine, with its roots. It sends out runners that take root at convenient distances.

A barley plant or an oat plant has roots that stretch several feet into the ground; if you measure the length of each root and rootlet and add all the lengths together it amounts to fifty feet or more. An animal can move about and find its food. A plant is fixed to one spot and must send out its roots to find the food it needs.

Most roots grow in the ground. Some vines, like the Poison-ivy, or the Trumpet-vine, have little roots that are all above ground, in the air (*aërial* rootlets they are called), by which they climb. Water-plants have few roots. Their food comes to them ready made. Marsh-plants have more roots, and land-plants most of all.

FIG. 217. A mangrove swamp. The roots of the trees are more than half out of the ground. They hold up the tree as a mast is held up by ropes.

The Stems of Plants. — Plants are made up of two kinds of material — *cell-tissue* and *wood.* The stems of herbs contain little wood and much tissue; they are soft and fleshy. The stems of trees are nearly all woody. There are two kinds of stems. In the first kind the growth is from the inside outwards. Plants with this kind of stems are *endogens.* The stem of a sunflower or a cornstalk is a good example.

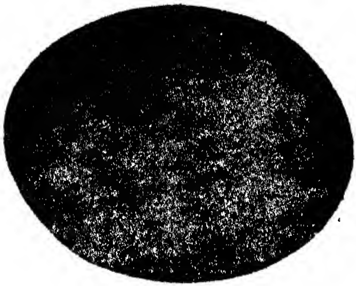


FIG. 210. A corn stalk cut across so as to show the bundles of fibers. (The pupil should cut and split a corn stalk and see for himself.)

Our common trees grow in a different way. Every year they add a ring or layer of wood on the outside of the stem (but inside of the bark). If you count the number of rings you can tell how old the tree is. The thickening of the tree is all on the outside, so that the oldest wood — the *heart* of the tree — is on the inside, and the youngest — the *sap-wood* — is just underneath the bark. The heart-wood is dead; the sap-wood alive. (The pupil should examine a slice of the trunk of a tree and count the rings and notice the way the bark grows around the fresh sap-wood.)

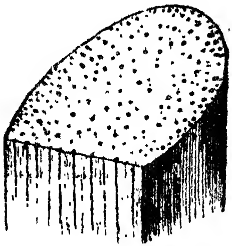


FIG 220. The stem of palm tree several years old. It grows from the inside outwards. It is, like the corn stalk, endogenous. It grows by adding new material on the inside. The new fibers are mixed in among the old.

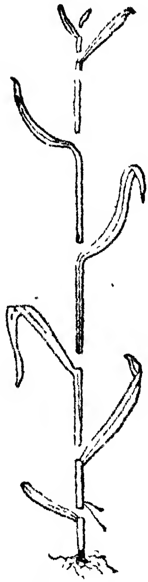


FIG 221. The plan on which Indian corn (maize) is built. The stalk has here been cut into pieces. Each piece is on the same plan. Every tree and every plant is built on a certain plan. The plant keeps on carrying out this plan over and over again.

A coral island is, in many ways, like a tree. The coral near the surface of the water is full of life—like the sap-wood and the leaves of a growing tree. The coral deeper down was once alive and is now dead—like the heart-wood of the tree. In the coral island, as in the tree, a colony of live growing cells is built on a foundation of cells once alive and now quite dead.

The stem of a plant bears leaves and buds; the root of a plant has no buds. This is a general rule, and is the way to tell a stem from a root. A few plants have underground stems just as a few plants have roots in the air. The Irish potato we call, in common language, a root; but it is really an underground stem.

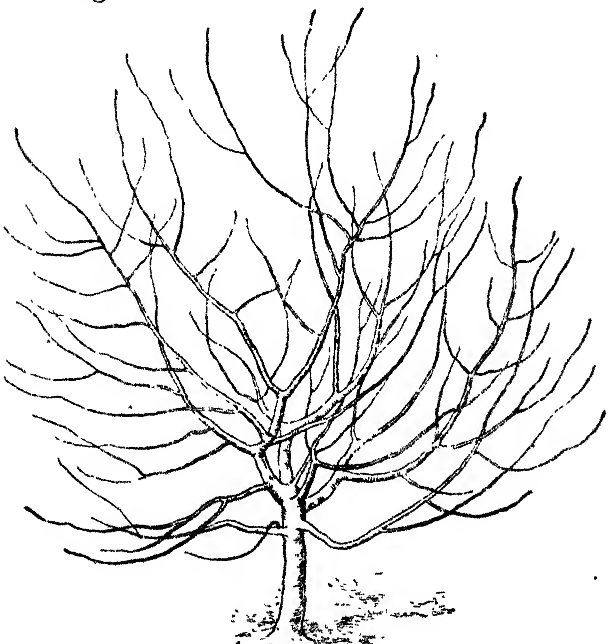


FIG. 222. The branches of a sour-cherry tree. Notice that in this tree the stem is lost in the branches. Maples, oaks, elms and other trees have stems of this sort.

Branches.—All the branches of the same oak tree are somewhat alike, and no two of them are exactly alike. The branches of all white oak trees are somewhat alike. You would know them anywhere for white oak branches, but it would be hard to find, in the whole country, two branches exactly alike. The branches of a tree grow from buds. A bud that is on the south side of a tree gets more sunlight, and makes a better branch than a bud on the north side. Some branches die when they are very young; some live but do not flourish; some have enough sunlight, but not quite enough food. There is a struggle for existence among branches as there is among animals. The branch or the leaf that gets the most food and the most sun-

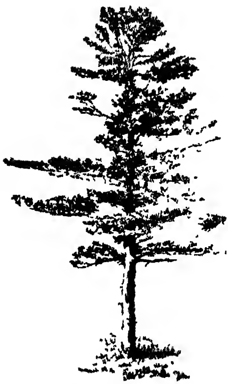


FIG. 223. The branches of a pine tree. Notice that in this tree the stem goes to the very top and the branches stream out from it.

FIG. 224. A mullein stalk, which does not have branches. The buds grow close to the stem.

light grows best and lives the longest and healthiest life.

Winter Buds.—A plant gets its food from the soil through the roots and when the spring comes it begins to grow quickly after its winter sleep. During the warm weather the tree or plant is full of leaves. If you look at the branch of a tree just where the stalk of a leaf joins the branch, you will find a little bud—a winter bud, so called. (Try it.)

FIG. 225. Maple leaves. Notice the winter buds at the foot of the stalk of each leaf next the branch. There are winter buds at the end of the shoot also.

Fall of the Leaf.—In most of our trees the leaves fall in autumn (called "the fall"). Their work is done. They are ripe and die, even before the frost kills them. The stem falls off with the leaf and leaves a *scar*.

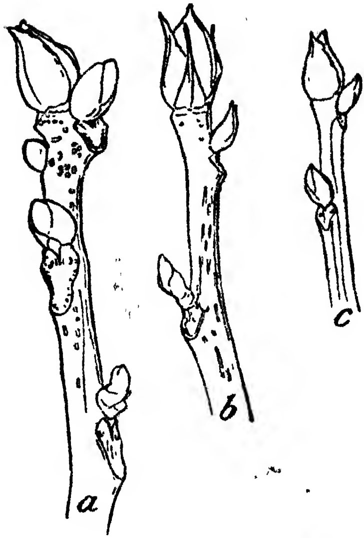


FIG. 226. Leaf-scars of hickory trees. Above each scar you can see the winter bud. The bud becomes a growing point next spring.

Evergreens are trees and shrubs in which the leaves do not fall in the winter.

Buds.—In the growing season the buds are small and many persons do not notice them. In the winter the bud is tightly wrapped up, but it is easy to see because the leaf is out of the way. In the spring the buds grow to be branches, and new leaves grow on the new branches or shoots.

It is easy to make the bud swell in a room in winter-time, even. Cut some branches two or three feet long—from a red maple tree, a lilac bush, a peach tree, an apple tree, etc.—in the winter. Put them into jars or vases of water just as if they were flowers. Renew the water every day or two and cut off the bottoms of the branches once a week so as to give a fresh surface there. In a week or two the buds will begin to swell. In two or three weeks flowers will appear. Such branches flower best in a room that is not lighted with gas. They flower more quickly if the vases are set in the sunshine for a few hours every day.

Leaves.—A complete leaf has three parts—the blade, the foot-stalk that fastens the leaf to the branch, and the *stipules* (which are often green and leaf-like themselves).

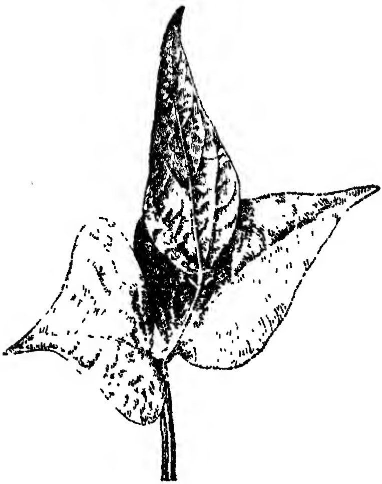


FIG. 227. Three complete leaves of a bean-plant. Notice the leaf whose blade is upright: it has a foot-stalk and stipules.

The pupil should gather several different kinds of leaves and examine them carefully. The blade of the leaf is made up of green pulp covered with a thin skin. It is supported by a kind of framework of thick pieces—the *ribs*. Usually there is a rib in the middle—the *mid-rib*—and other smaller ones called *veins* and *veinlets*. Hold a leaf up against the light and you will see how it is covered by a network of veins. If you press leaves in the summer-time, you can have plenty of specimens to examine in the winter.

The Shapes of Leaves.—Leaves are of all kinds of shapes and each shape has a particular name. The names are given here so that when you read the description of a plant, you will know what shape is meant. For instance, the leaves of a willow or peach-tree are lanceolate like the fourth figure below.

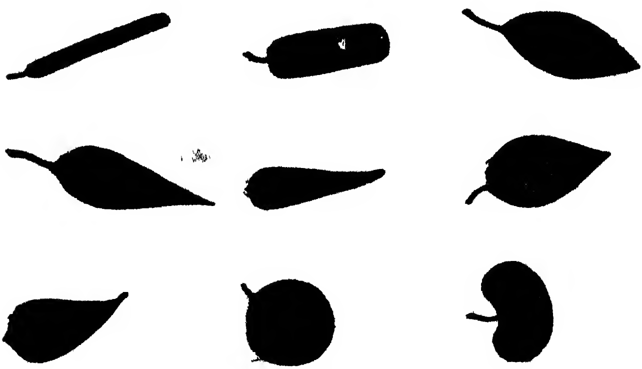


FIG. 228. Linear, oblong, elliptic, lanceolate, spatulate, ovate, obovate, orbicular, reniform, leaves.

Leaves Love the Sunlight.—The more sunlight a leaf gets the larger it grows. Leaves are arranged on a tree so that, on the whole, each leaf gets its share of sunlight and air.

FIG. 229. Leaves of the Norway Maple. Notice that the leaves that have had the most light are the largest.

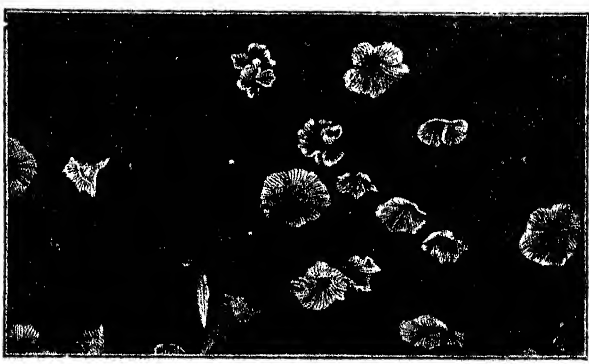


FIG. 230. Leaves and flowers looking for sunlight.

(p. 258)

Arrangement of the Leaves on the Shoot.—The leaves (and the buds from which next year's leaves

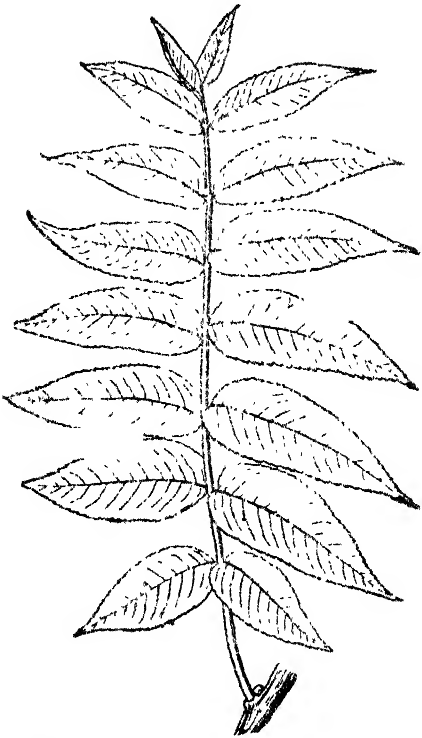


FIG. 231. The leaves of the black Walnut tree are arranged in pairs; each leaf of the pair is *opposite* the other.

are to spring) are arranged on the shoot in two ways. Either the buds are *opposite* each other, or they are *alternate*.

FIG. 232 The leaves of a Mulberry shoot are *alternate*. The leaves are not arranged in pairs, but one by one.

Breathing-pores (or Holes) in Leaves. – Every leaf has a framework of ribs and veins that hold it together like the ribs of an umbrella. The blade of the leaf is very thin, but when it is looked at under a microscope it is seen to have thousands of little pores, or breathing holes.

On the lower surface of each leaf of a lilac bush there are more than 150,000 breathing holes to

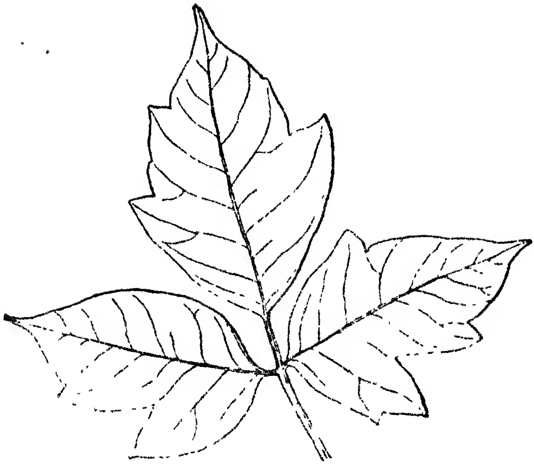


FIG. 233. The leaf of Poison-Ivy. Notice the ribs and veins. (Be careful not to handle it.)

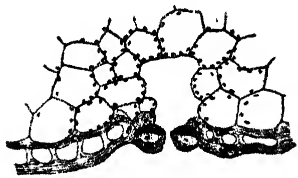


FIG 234. Part of the thickness of an ivy leaf, very much magnified. The bottom of the picture shows part of the bottom of the leaf. The breathing holes are on the under side of the leaf. One of them is shown in the picture surrounded by cells that make up the leaf itself. The leaf takes in air and carbonic acid gas through thousands of pores of the sort. The leaf breathes in this way.

every square inch! Each leaf has several hundred thousand pores, and the whole bush has millions and millions. The breathing holes take in air and carbonic acid gas. Plants need the oxygen of the air as animals do, only they do not need so much of it. Plants also need carbonic acid gas. They breathe it in. When animals breathe, they breathe carbonic acid *out;* if they breathe it in they die. This is one of the chief differences between animals and plants. Remember that animals have pores in their bodies. Perspiration comes from pores in the skin. A man's body has over 2,000,000 pores.

FIG. 235. Plants give off water-vapor from their leaves.

Leaves Give off the Vapor of Water from their Surfaces. — The water taken in by the roots of a plant rises through the whole plant and a great deal of it is given back to the air from the leaves as invisible vapor.

You can prove this as follows: Cut off a green shoot of any plant (rhubarb, for instance) and put the end of the shoot through a hole in a cork and stand the shoot in a bottle of water. Put a tumbler upside down over the shoot and its leaves, and notice that a mist soon shows on the inside of the glass. The green shoot sucks up the water. The leaves use all they need for food. What they do not need they give off as invisible water-vapor, and this vapor soon fills the inside of the tumbler. The cold tumbler condenses the invisible water-vapor into visible drops (just as the invisible water-vapor of your breath is condensed when you breathe against a cold window-pane.) (Try it.)

Why the Shade of a Tree is Cool.—The shade of a tree is cool in the first place, because the leaves keep off the direct sunshine. It is also cool because the water-vapor given off by the leaves is always evaporating—and whenever water evaporates, becomes vapor, it uses up heat to do it, and leaves the space round about much cooler. Tie a wet towel round your head. The water will evaporate and leave the towel nearly dry. As it does this your forehead will become cooler.

How Plants Get their Food.—A green plant gets its food *first*, from the soil, through its roots; *second*, from the air, through its leaves.

Dry a green plant thoroughly in an oven. Water will pass off. *All this water came from the soil.* Burn the dried plant in a fire. Gas will pass off and ashes will remain. *All the elements that came from the air were in the gas. All the ash came from the soil.*

Plants contain much carbon; and you know this because by burning a mass of plants or trees you can make charcoal—which is nearly pure carbon. About half of a dried dead tree is carbon.

A Green Plant gets its Carbon from the Air.—The plant breathes in air (air is a mixture of nitrogen and oxygen gases, with a small amount of carbonic acid gas), and sucks the carbonic acid gas into the little cells inside the plant. If you put a piece of *caustic potash* into a mixture of several different kinds of gases the potash will absorb all the carbonic acid gas out of the mixture and leave the rest. We know that it does so, although we may not know exactly why. In somewhat the same way the leaf absorbs all the carbonic acid gas out of the air and leaves the nitrogen. We do not know exactly why but we know that it does so.

During sunlight carbonic acid gas is breathed in by the green leaf and some oxygen gas is breathed out.

A tree needs all or nearly all of its leaves in order to make food enough to live. If you strip half the leaves from a tree it will die.

FIG. 236. A green leaf of a water-plant placed in a tumbler of water will give off bubbles. Some of these bubbles are air but most of them are oxygen gas.

The Plant Makes Starch for Its Food.—Starch (like our common starch) is made out of carbon, hydrogen and oxygen; $C_6H_{10}O_5$. The plant makes starch out of carbonic acid gas (CO_2) and water (OH_2). All green leaves in the sunlight can and do make starch. It is the sunlight that does the work. Leaves kept in the dark cannot make starch and therefore can not make food enough for the tree.

The Plant Changes its Starch into Sugar.—Starch is $C_6H_{10}O_5$. Sugar is $C_{12}H_{22}O_{11}$. The starch cannot be dissolved in water and therefore is not fit for plant-food, because plant-food must be able to be dissolved by the water that comes from the roots and thus to run all through the body of the plant. Plants turn their starch into sugar somewhat as starchy foods are turned to sugary foods by the saliva of one's mouth. Sugar *can* be dissolved in water and therefore the sugary water can and does run throughout the plant as *sap*. The sugar maple has a great deal of very sweet sap which, when boiled, makes maple-sugar.

The Sap.—The sap flows everywhere in the plant somewhat as blood flows in our veins. Some of it flows from the roots to the leaves; some of it flows from the leaves to the root. The sap from the roots takes up food from the soil; the leaf sends down its sap; the two together manufacture new vegetable protoplasm. Exactly how this is done no one knows yet; but it is done. The life of a plant goes on somewhat like the life of an animal.[1] It takes in food, digests it, sends it to all parts of its body, manufactures cells of protoplasm. These cells multiply and the plant grows. When the protoplasm in the cells dies, the plant (or the animal) dies.

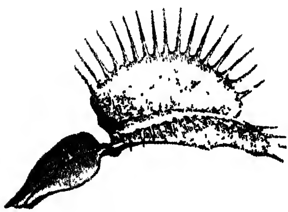


FIG. 237. Leaves of the Venus' Fly-Trap.

Plants that Catch Flies for Food.—There is a plant in America called Venus' Fly Trap that catches flies and eats them! Three hairs on each leaf are very sensitive like the whiskers of a cat. When a fly touches one of these hairs the leaf closes up with a snap and holds the fly fast. If the fly is alive the leaf keeps closed and sucks the fly dry and then opens. If it is dead the leaf opens almost at once. Somehow the leaf is able to tell that a dead fly is not the food it wants. Blue-bottle flies, spiders, caterpillars and even bits of raw meat are greedily taken by this plant as food.

Flower-branches.—The branches on which flowers grow are born from the winter-buds. Some-

[1] The life of a *tree* is more like the life of the colony of animals that make up a coral bank (see page 246)

times the flowers grow directly on the stem as in the mullein-plant. (See Fig. 224.)

Solitary flowers often grow on the end of the main shoot as in the common white-weed (ox-eye daisy) of our fields.

What Flowers Are For.—The plant bears flowers in order that they may produce seeds and in order that the seeds may produce other plants of the same sort. A single elm-tree might live its own life out without producing seed, but if no elms produced seed there would soon come a time when no more elms would be found on the earth. If none of the Smith or Jones families had children the very names would soon die out.

FIG. 238. Hyacinth flowers grow from buds on the stem of the plant; as does mignonette, etc.

We are apt to think that the beauty and scent of the flowers are made for us—for men. We certainly get the benefit of them. We shall, however, soon see that the flower is a wonderful arrangement for producing seed, for protecting it when it is produced, and for making it fruitful. The color and scent and honey of the flowers are for birds and bees, not for us; but we can enjoy them, all the same.

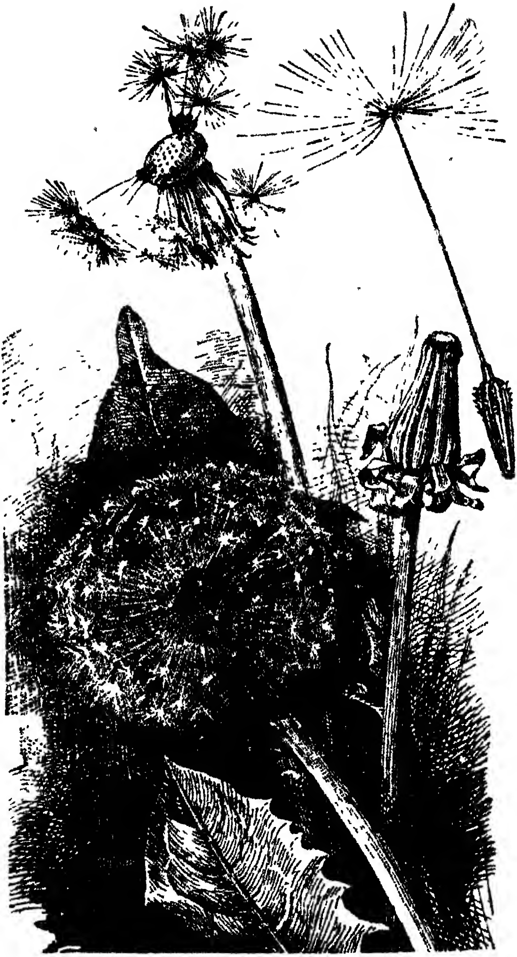


FIG. 239. The dandelion bears a solitary flower at the end of the stalk.

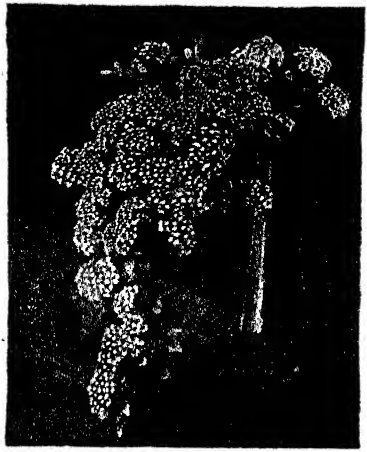


FIG. 240. The flowers of the Bridal Wreath (Spiréa) are borne in clusters, many clusters on a branch.

The *calyx* of a flower is the outer and lower green cover. You can see it in the picture of the buttercup sliced in two. (Fig. 242.) Let us call this cover a *whorl* (that is a whirl—a circle—that makes a part of the flower). The next whorl is called the *corolla*. It is made up of the five bright yellow

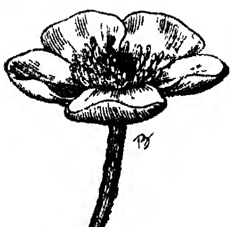


FIG. 241. A buttercup flower.

FIG. 242. A buttercup flower sliced in two.

leaves of the buttercup flower. Double roses have many leaves in their corollas.

A calyx often has several leaves; each one of them is called a *sepal.*

A corolla usually has several leaves; each one of them is called a *petal.*

A flower is borne on the thickened end of the flower-stalk; this end is called a *torus.*

Look at the last pictures again. Inside of the petals of the buttercup you will see: *first*, the *stamens* of the flower (that is the little rods that stand up highest, each rod having a thickened end); and, *second*, the *pistils* (that is the little clump inside of the ring of the *stamens*). The pistil is the seed-bearing part of the flower. You must examine all sorts of flowers and find the *stamens*

FIG. 243. A hollyhock flower sliced into two. **The fine little hairs with thickened ends are the *stamens* (point them out). The clump in the middle of the flower is made up of *pistils* (point to it).**

and *pistils* in each one, if you can. They are differently arranged in different flowers. Notice that the ends of the stamens are always thickened. The thickened end of a stamen is called its *anther*. (Point out the *anther* in the last three pictures—and find them in real flowers.)

Pollen is Borne by the Stamens.—Pollen is the dust-like grains on the anther. The violet produces about a hundred grains of pollen in each blossom, while the poppy produces more than three million grains, and some flowers (orchids for instance) many millions.

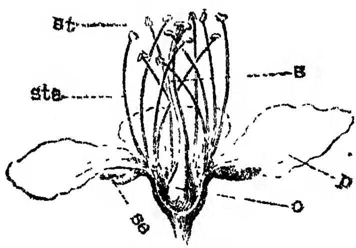


FIG. 244. A plum blossom sliced in two to show: *se*, the sepals; *p*, the petals; *sta*, the stamens. The pistil occupies the middle of the blossom and consists of three parts: *o*, the ovary; *s*, the style; *st*, the stigma.

The Seeds are Borne by the Pistils.—The ovary (*o*) ripens into the fruit. The anthers of the stamens (*sta*—not *s*, not *st*) are tipped with pollen.

Fertilization of Flowers.—Flowers will not produce seeds unless the egg-cells in the ovary (*o*) are fertilized (made fertile, made productive) by pollen-cells from the anthers.

A grain of pollen falls on the stigma (*st* in the last picture). There it absorbs the juices of the stigma and grows a fine hair-like tube. This tube grows downward through the style (*s* in Fig. 244) and reaches the ovary (*o*). When the pollen-cell meets an egg-cell in the ovary, the two join and the egg-cell ripens into a seed.

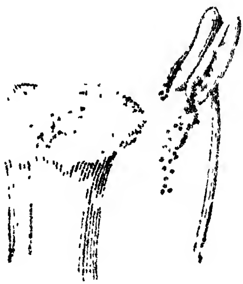


FIG. 245. In the right-hand part (*B*) you see the pollen of a plum blossom escaping from the anther. It falls on the stigma (*A*). It sends out fine shoots that are carried down the style to the ovary. There they meet with and fertilize the egg-cells. Each fertile egg-cell grows into a seed.

Fertilization of Flowers. — A flower may be fertilized by its own pollen; but the seeds grow best if they are fertilized by the pollen from other flowers.

Cross-fertilization is the fertilization of the egg-cells of one flower by the pollen from another flower.

Pollen is carried by the winds from flower to flower.

Pollen is also carried by insects and bees from flower to flower.

Plants that depend upon the wind for bringing pollen to them usually have small flowers with little odor. They do not need to attract the bees by their odor. Flowers that are fertilized by pollen carried by bees usually have large gay flowers with a strong odor. Grasses are fertilized by pollen borne by the wind and so are oak trees, birches, elm trees, poplars and pine trees. The flowers of such trees do not close at night. They must always be ready to catch what pollen the wind brings. Flowers that close at night are usually fertilized by pollen carried by bees. The bees do not fly by night.

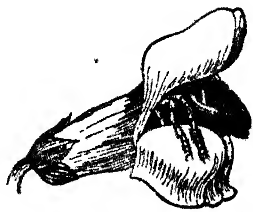


FIG. 246. The pollen of this flower is dusted over the back of the busy bee who enters the flower to get its nectar, its honey. When he enters another flower of the same sort he leaves pollen there, and thus the second flower is cross-fertilized. Strawberry plants, for instance, are fertilized entirely by bees.

If all the bees in the world should suddenly die, more than 100,000 species of flowers would perish, too. The bees can not live without the flowers, the flowers cannot live without the bees, and mankind would find it very inconvenient to live without the fruits which the bees help to fertilize when they are flowers.

Fruits.—The ovary filled with seeds ripens into the fruit. It may be a berry, a stone-fruit, a nut, a grain, or a pod. Hickory nuts, chestnuts, acorns, are fruits just the same as peaches, apples, etc. Beans and peas bear pods as fruit. Think of all the fruits you know; and say where the seeds are in each kind.

Life in Seeds.—A seed is alive—the protoplasm in it is alive—but it does not begin to grow until

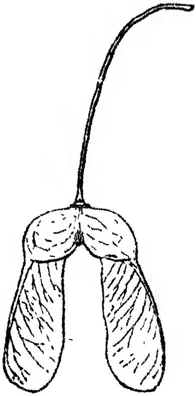


FIG. 247. The fruit of the black maple. Fruits of this shape are called key-fruits.

the spring comes. Seeds in a dry place will keep alive for several years — some for more than fifty years. But the stories about "Mummy-wheat" grown from seeds found in the coffins of Egyptian mummies where they had been for thousands of years are not true.

How Seeds are Scattered. — When the fruit is ripe the seeds are ready for planting. Usually the tree has to do its own planting. The tree that bears the most seeds and scatters them furthest abroad has the best chance of producing new trees of its own kind. Such trees are, then, most numerous.

The seeds of the dandelion and thistle are carried by the wind. Some seed-vessels burst when they are ripe and scatter the seeds in this way. Birds eat fruits and digest the pulp but excrete the seeds, and thus scatter them. Fruits with burs cling to the fur of animals and are thus scattered far and wide. Nuts are buried by squirrels; some of them

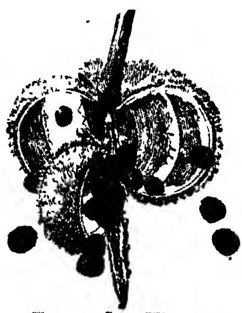


FIG. 248. The seed-pod of the balsam plant explodes and scatters the seeds.

are not eaten but grow to be trees. Finally, men plant the seeds of the plants they value and take care of the young plants. The plants cared for by men have, accordingly, a great advantage in the struggle for existence.

How Seeds Grow to be Plants.—Each seed contains a young plant all ready to grow.

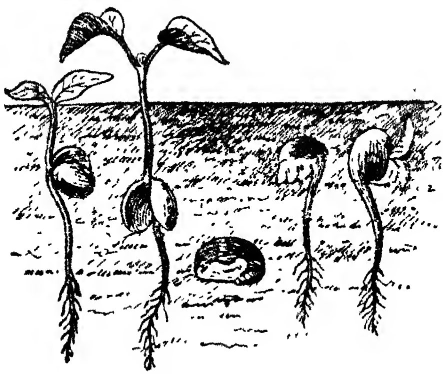


FIG. 249. A seed in the ground (the middle one in the picture) grows a root, and a stem, and leaves, and becomes a complete plant. The original seed contained a young plant all ready to grow.

Take an almond out of its shell. Soak it a little in water and pull off the thin brown outer coat. At one end of the meat you will find a little plant, or bud (called the *plumule*), all ready to grow. (Try it.) The meat inside a cherry seed is like an almond and you can find the plumule there too. (Try it.) Open a fresh morning-glory seed; or a dried one that has been well soaked in hot water and see what you'll find. (Try it.)

Plants Sometimes Grow from Buds.—Cut up a potato leaving a bud or "eye" in each piece and plant the pieces. A plant will grow from each piece. (Try it.)

Plants Sometimes Grow from Cuttings.—A bit of rose, or geranium or carnation stem may grow if it is stuck in the ground.

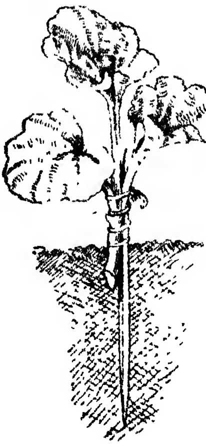


FIG. 250. A geranium grown from a cutting. The short cutting is tied to a wooden toothpick to keep it upright.

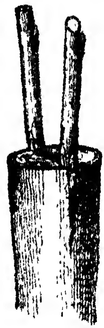


FIG. 251. Cion of Apple. The Cion Inserted. The parts must be well waxed to keep out the air.

(Try it.) The tips of strong upright shoots make the best cuttings. Each cutting should have a joint near its lower end. They should be planted in a box about five inches deep filled with loose sandy soil. In about a month, roots will form and new leaves will come at the tips. Then they may be transplanted.

Fruit Trees Grow from Grafts on the Stems of Other Trees.—The *cions* (slips from the tree) are often grafted into the stems or branches of other trees.

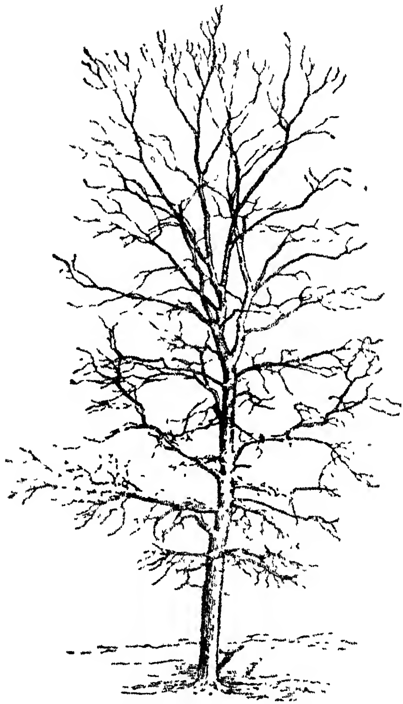


FIG. 252. The small-fruited shagbark hickory in the winter time.

Such grafting is done in the spring, using cions cut in the winter. Pears grafted on quince trees grow well; but quinces grafted on pears do not grow so well. Tomato plants grafted on potato plants and also potato plants grafted on tomato plants grow well. When the potato is the root, both tomatoes and potatoes may be produced. When the tomato is the root, neither tomatoes nor potatoes are produced. Chestnuts can be made to grow on some kinds of oak trees but not on others. The reasons for these things are not well understood. We have to find out what a graft will do by trying the experiment.

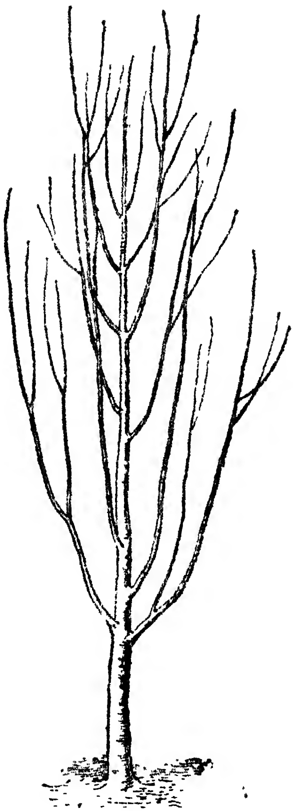


FIG. 253. The sweet cherry in the winter time.

The Forms of Plants.—There are differences in the leaves on the same oak tree, differences in the stems and branches of different white-oak trees and yet, in a general way all white-oaks look alike. All red-woods look alike; all elms look alike. *Each tree and each kind of plant has its own habit of growing.* Oak trees have a habit of growing in a certain form just as tigers or sheep grow in a certain form. New branches grow in the same form every year because they grow from buds which are arranged always on the same plan in each tree.

FIG. 254 A live oak tree in Florida, with Spanish moss hanging down from its branches.

Trees Suggest Certain Feelings.—The oak-tree is strong and sturdy; the lady-birch is slender and graceful; the cypress is gloomy; the pine is solemn; the red-wood is majestic. When we look at any of these trees they give us feelings of pleasure or, it may be, of gloominess or pain. To be in a red-wood grove is like being in a grand church.

That is because the light of the sky comes to you from far over-head in such a grove, just as it does in a great cathedral. In the same way we have special feelings about the modest violet, the lovely wild rose, the formal dahlia, the pure white-lily, the flaunting peony, the stately oleander. the gay phlox.

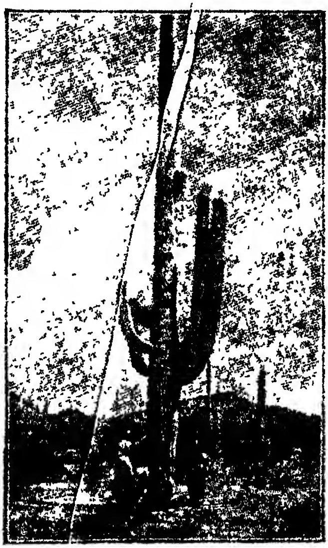


FIG. 255. A giant cactus on the Arizona desert.

If you look at any landscape and find it beautiful, you will find that there are three things that make up nearly all of your enjoyment: *First*, the shapes of the hills and valleys, *second*, the shapes of the clouds, and *third*, the colors and shapes of the trees and plants. If you imagine any one of these three things to be different either in shape or color your feeling about the landscape will change. Think of any fine view and imagine all its trees and all its grass to be dead. Your pleasure would go if they were to change. You owe them thanks for being what they are.

FIG. 256. Two of the "big trees" of California. Notice the man standing at the base of the nearest tree.

Age of Trees.—Some trees like the red-wood and the "big tree" (*Sequoia*) of California grow to a great height and are, no doubt, more than a thousand years old.

Olives, fig trees, yew trees live for many centuries. Oak trees may last for 1,500 years, cedars of Lebanon about half as long.

There is a cypress in Lombardy, 120 feet high and 23 feet in girth, that is nearly 2,000 years old. Francis the First, King of France, who died in 1547, drove his sword into it in despair after he had been defeated in a battle, and Napoleon I, Emperor of France, altered the road he was building across the Alps so as to spare it in 1800.*

The Struggle for Existence Among Plants, Trees, Leaves, Branches, etc.

The Earth is filled with plants. The strongest and fittest survive; the weaker perish. Plants struggle for room to grow in; for food and moisture in the soil; and for sunlight.

FIG. 257. The pine trees used up all the food and moisture in the soil and left none for other plants until man took a hand in the struggle and cut down some of the pines. Then, and not before, other plants grew in the open spaces and along the road-way.

Cacti will grow in deserts; eucalyptus trees where there is little water; mosses on rocks. They fit their surroundings. Live-oaks and willows and geraniums would die in such spots.

Colors and Odors of Flowers.—In 4,180 flowers of all kinds: 1,200 were *white*, 950 *yellow*, 920 *red*, 590 *blue*, 300 *violet*, 150 *green*, 50 *orange*, 20 *brown*. It is an advantage to a flower, then, to be white, yellow or red. More bees and birds see it and come to carry its pollen to other flowers of the same sort.

Of	the	1,200 white	flowers	187	had	a	smell.
"	"	950 yellow	"	75	"	"	"
"	"	920 red	"	85	"	"	"
"	"	590 blue	"	31	"	"	"
"	"	300 violet	"	23	"	"	"
"	"	150 green	"	12	"	"	"
"	"	50 orange	"	3	"	"	"
"	"	[illegible] brown	"	1	"	"	"

It is probable that bees and birds and insects are attracted by the smell of a flower even more than by its color.

The Gardener Helps Nature to Form Varieties of Plants.—Nature selects the best and strongest plants by making it difficult for the weak ones to live. Those plants that survive in the struggle for existence are very apt to be what we call weeds. But man wants wheat, barley, rye, grass, etc., and he helps these useful plants to grow by planting and cultivating them and by killing off the weeds. Moreover, the gardener saves the seeds of the strongest and best plants and sows them, but not the seeds of the poorer sort. The next year he again selects and sows the best seeds, and so on. Every plant inherits something from the seed which was its parent. So, finally, the gardener improves the plants he selects. His wheat is improved so as to give the greatest product of grain; his grasses to give the most hay; his apples to be the largest and best flavored; his flowers to be the largest, of the brightest colors and of the finest odors. He helps Nature to form the very varieties that he wants.

Varieties of animals are produced by the same kind of selection. A good trotting horse is the son of a long line of trotting horses. A good milch cow is the descendant of many generations of good milkers. In every generation man selected the best cows. The others were killed, perhaps, for beef.

Some of the Uses of Plants:

I. *Plants Purify the Air so that Animals can Breathe It.*—Animals breathe in air and use its oxygen in their lungs and breathe out carbonic acid gas. This poisonous gas (which no animal can breathe and live) is being constantly poured into the air by the breathing of animals. Plants breathe it in and use it for food, and they also breathe out oxygen. Plants keep the air pure for animals to breathe.

II. *Plants Make All the Food that Animals Live Upon.*—Some animals eat plants only (cows, sheep, rabbits, etc.). Without plants they could not live. Some animals feed upon smaller animals (lions and tigers do this). Some animals live on animal food and on plant food at the same time (men do this, for instance; they eat meat and vegetables and grain). Without plants there could be no animal life on the earth. Plants could live if there were no animals, but no animals could live if there were no plants.

III. *Plants Furnish Clothing for Men.*—Cotton and linen are made directly from plants; silk is spun by the silkworm that feeds on leaves; wool comes from sheep who are kept alive by grass.

IV. *Plants Supply all the Fuel in the World.*—Fire-wood and charcoal are made from trees. All the coal in the world is made from trees and plants of long-past ages.

V. *Plants Give Us the Artificial Light that Men Use.*—Gas for burning is made from coal-fossil plants; kerosene is coal-oil; electric lighting is done by dynamos that are usually run by steam engines (a few dynamos are run by water-power, but even here, their lamps have carbons (coal) for making the light)

VI. *All Steam-engines Get Their Energy From Plants.*—The coal, or wood, or petroleum used as fuel by steam engines is the product of plants, so that everything in the world that is made by a steam-engine, or driven by a steam-engine, depends directly upon plants. Cotton cloth, for instance, is woven by steam-driven machinery, and it is carried from Boston to San Francisco and from San Francisco to Manila by locomotives and steam-ships.

All the Life in the World, Then, Depends Upon Plants.—But p' nts cannot grow without sunshine, so that, finally, we may say that *all* the life on the earth and in the solar system depends upon the sun. When the sun stops shining all the solar system will die.

Arbor-Day.—Americans, especially in the far West, have learned the value of trees and in many states there is a holiday in the spring on which school-children and others plant trees in places where they are needed. Millions of trees are now growing on land that was once treeless.

Number of Plants.—There are at least 125,000 *known* species of seed-bearing plants. We do not yet know half the plants of Africa, South America and China.

Species.—Each kind of plant forms a species. The white oaks form one species, the red oaks another, and so on.

Names of Species.—Since Linnæus, the father of modern botany, published his book on the species of plants (*Species Plantarum*) in 1753 all species are known by two Latin names. Thus the white oak is called *Quercus* (oak) *alba* (white). *Quercus* is the name for all the oaks, *alba* is the particular name for the white species. (We say *Quercus alba* just as one might say "Smith-John.")

Oak Trees.—To show you how different species in the same *family* differ and how they resemble each other some of the oaks and some of the cone-bearing trees (pine trees, etc.) are here described. A complete botany would give descriptions like these for every known species of tree and shrub, and plant and herb.

Cone-Bearing Trees.—*The White Pine* is a large forest tree much used for lumber. Its leaves are long and soft, light green, arranged in groups of five. *The Pitch Pine* is a medium-sized tree. Its leaves are arranged in threes.

FIG. 258. The acorn of the White-Oak

FIG. 259. The acorn of the Red-Oak.

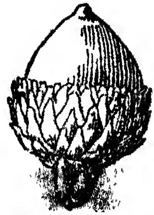


FIG. 260. The acorn of the Black-Oak.

FIG. 261. The acorn of the Bur Oak

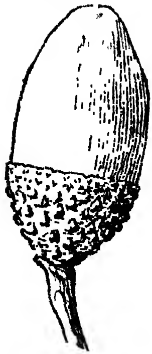


FIG. 262. The acorn of the Chestnut-Oak.

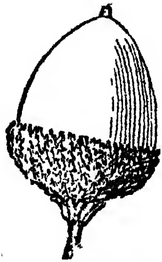


FIG. 263. The acorn of the Swamp White-Oak.

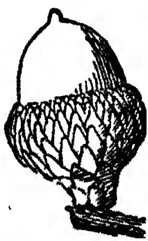


FIG. 264. The acorn of the Scarlet-Oak.

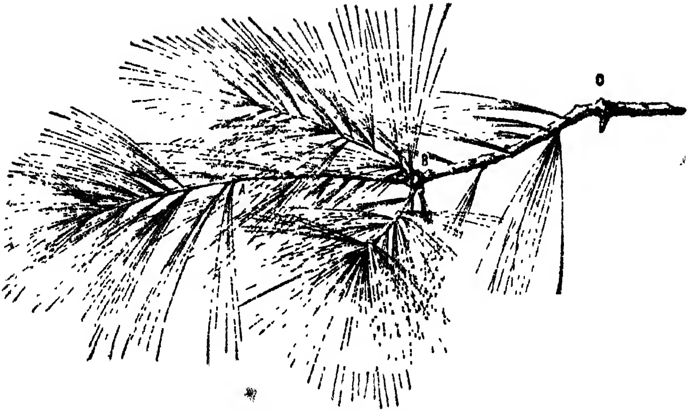


FIG. 265. Shoot of White Pine, one-third as large as life. From the tip of the branch to *A* is the last season's growth; from *A* to *B* it is two years old; from *B* to *C* it is three years old.

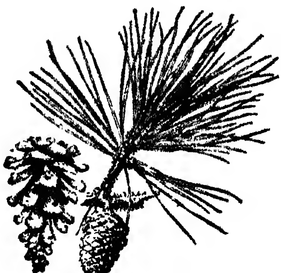


FIG. 266. The Pitch Pine. An old open cone is shown on the left hand side of the picture.

FIG. 267. The cone and foliage of the Black Spruce.

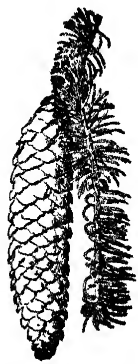


FIG. 268. The cone of the Norway Spruce, a common evergreen in the United States.

FIG. 269. The cone and foliage of the Hemlock.

FIG. 270. The cone and foliage of the Arbor-vitæ (used in evergreen hedges).

Make a Collection of Dried Plants.—Plants can be preserved by drying and pressing them between blotting paper cut into sheets 12 x 18 inches. For each species there should be at least one specimen of the stem, foliage, flower, root and fruit, properly and neatly labeled. After the plants are thoroughly dry they can be fastened (gummed down by strips of paper) to strong white writing paper.

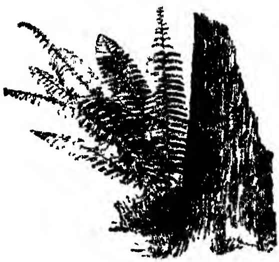


FIG. 271. The Christmas Fern, which remains green all winter.

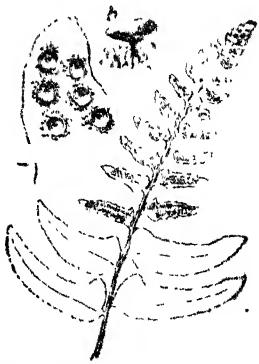


FIG. 272. The underside of the leaves of the Christmas Fern are covered with little brown spots. Each of these spots (shown magnified at *a*) is covered with a little shield (*b*) and contains fine brown dust. From this dust new ferns will grow. It is not a seed, because it did not come from a flower.

Put Only One Species on a Sheet.—The label of each sheet should give: The name of the collector; the place where the plant was found; the date when found; remarks as to the height, color, etc., of the plant, the nature of the soil, etc., and finally the English and Latin name of the plant. Consult any large illustrated dictionary or encyclopædia, or work on botany, for help in finding the names; or ask some one who knows.

Ferns, Mosses, Mushrooms.—All the plants that we have so far studied bear flowers and produce seeds. Their seeds, in turn, produce new plants. There is another kind of plants (ferns, mosses and mushrooms) that do not flower and have no seeds.

There is not room in this little book to say more about this class of plants, or to say anything about *fossil plants* or *bacteria.*

BOOK VIII: THE HUMAN BODY.[1]

Physiology is the science that teaches us the uses of all the parts of the body of an animal and explains the ways in which they do their work. This book will describe the uses of the parts of the human body, and there is only room to describe the most important parts.

Ana'tomy describes the form and uses of the bones, tissues, muscles, etc.

Hygiene (pronounced hī' ēn) tells how the body may be kept healthy.

[1] Note to Teachers.—The subject treated in this chapter is so important, and at the same time so difficult, that a number of fundamental matters are insisted upon, in various places and in different manners, in order that the pupil may not fail to note their significance. Space is used in these repetitions that it is possible might better have been bestowed upon other topics which are passed over with slight mention, or omitted entirely. It is believed that the method adopted will prove itself to be the wise one, however. It is far better that the pupil should have a firm grasp on a few things, than a merely superficial acquaintance with many. The application of the principles here explained to the art of healthy living is hygiene. The exposition of the laws of hygiene is here left, to a very great degree, to the teacher, who should not fail to point out the injurious effects of stimulants and of tobacco upon the separate organs, upon the general health, and upon the morale.

Man is a Vertebrate Animal.—Human beings are *vertebrates*, that is animals with backbones. The vertebrate animals are man, beasts, birds, reptiles and fishes.

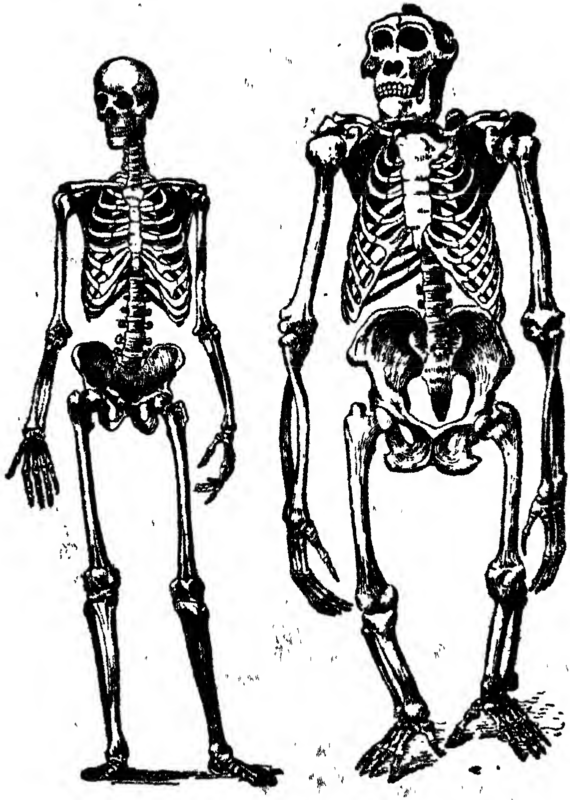


FIG. 273. Skeletons of a man and of a gorilla. They are alike, bone for bone.

The highest classes of vertebrate animals are men, monkeys and four-footed beasts. They are called *Mammalia* because their young are suckled at the breast (Mamma is the Latin for breast). All the mammals have red warm blood.

The Human Skeleton seen sidewise (see Fig. 274).

Na. = the bones of the Nose,
Fr. = the Frontal bone,
Pa. = the Pari′etal bones,
Oc. = the Occip′ital bone,
Mn. = the Man′dible (lower jaw).
} These bones are in the SKULL.

St. = the Sternum (breast-bone),
R. = the Ribs,
R′. = the Car′tilages of the ribs.
} These form the cavity of the THORAX.

S. = the Sa′crum.
Cx. = the Coccyx.
Scp. = the Sca′pula (shoulder-blade).
Cl. = the Cla′vicle (collar-bone).

H. = the Hu′merus (upper arm bone),
Ra. = the Ra′dius (lower arm bone),
U. = the Ul′na (lower arm bone),
Mc. = the Metacar′pus (hand bone),
D. = the Digits (fingers),
} These are in the ARM and in the HAND.

Il. = the Ilium,
Pb. = the Pubis,
Is. = the Ischium.
} These, together, form the HIP-BONE.

F. = the Femur (upper leg bone) (thigh bone),
Tb. = the Tibia (lower leg bone),
Fb. = the Fibula (lower leg bone),
T. = the Tarsus (ankle bones),
Mt. = the Metatarsus (foot bones),
D. = the Digits (toes).
} These are in the LEG and in the FOOT.

The names are Latin names, because early scientific books were written in Latin.

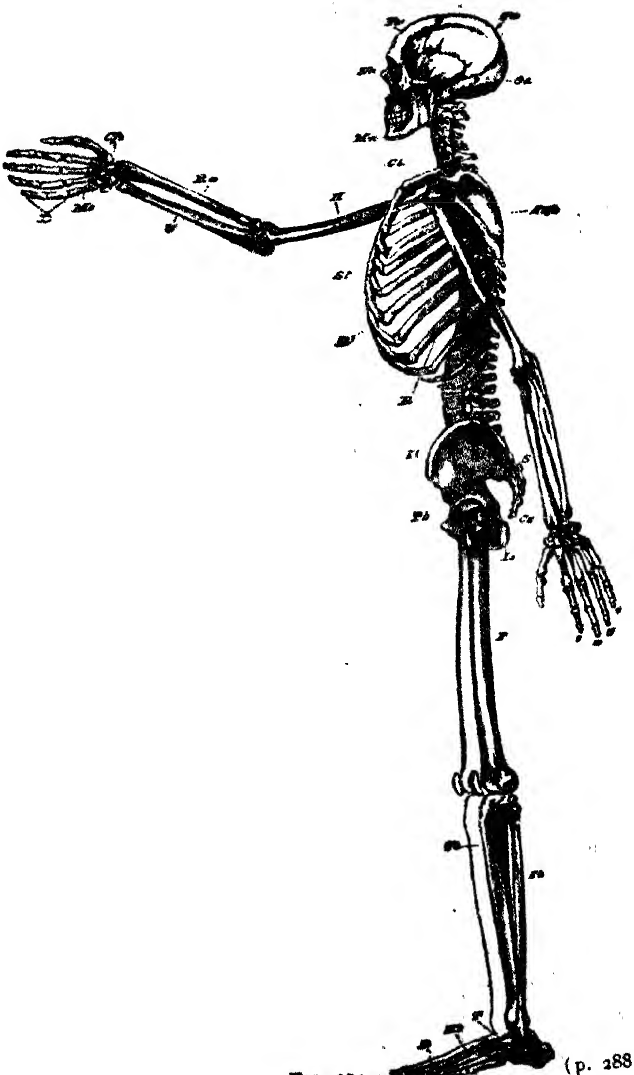


FIG. 274. (p. 288)

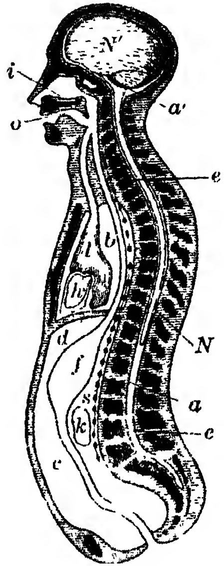


FIG. 275. The plan of the human body. If a dead body were to be frozen and then cut in two down the middle it would show somewhat as in the picture. The blackest parts of the picture stand for bones. *N'* is the cavity of the skull in which the *brain* lies. The brain is connected with the spinal-marrow or *spinal cord* (*N*) in the hollow part of the backbone (*ee*). The brain and spinal cord fill up a space that is called the *dorsal cavity* (*dorsal* means back). In front of the backbone is the *ventral cavity* (*ventral* means stomach). *i* is the cavity of the *nose*; *o*, the cavity of the *mouth*; *l* is the *lungs* (connected with the mouth by the *windpipe*); *h* is the *heart*, *f* is the *stomach*; the tube leading from the mouth to the stomach is the *gullet*; the tube from the stomach to the lower end of the body is the *intestine*; *k* is a *kidney*; *d* is a partition called the *diaphragm*.

The Human Body is Built on a Plan.—The stems and branches of a tree are built on a plan; and just in the same way the bodies of men and animals are built on a plan. All vertebrate animals have a backbone and contain two main cavites—the

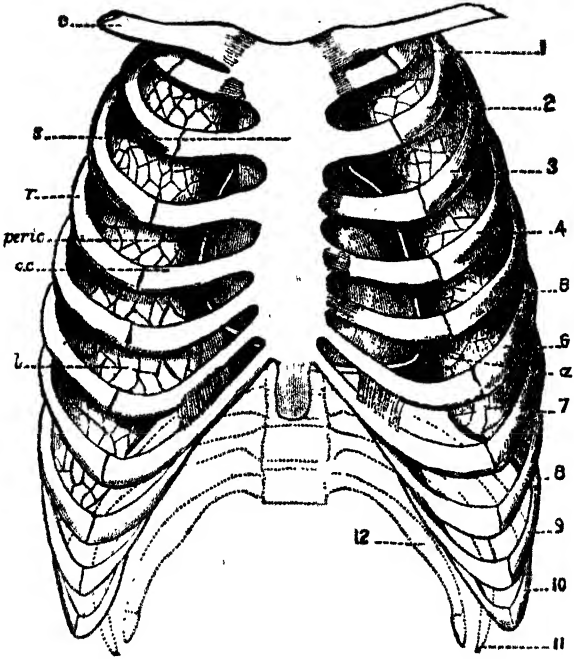


FIG. 276. The chest (*thorax*) and the ribs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 are the ribs, *s* is the breast-bone (*sternum*); *c* is the collar-bone (*clavicle*). You can feel on your own body where these bones are. Inside them are the lungs *l* (on both sides of your body—a right lung and a left lung); and also the heart (*a*) enclosed in a bag called the *pericardium* (*peric.* in the picture). Breathe deeply and you will know where your lungs are. Put your hand on the upper left side of your chest and you will feel your heart beat.

dorsal and the ventral cavities (NN′ is the dorsal, (*b*, *c*) is the ventral cavity in Fig. 275). All ***mammals*** have the ventral cavity divided into two parts, the *chest* (*b*) and the *ab'domen* (*c*) by a ***diaphragm*** or partition (*d*).

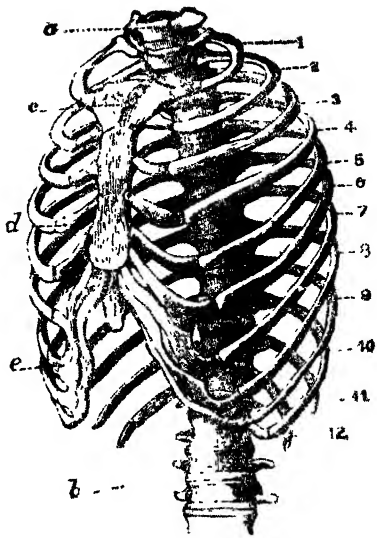


FIG. 277 The bony walls of the chest (*thorax*) and part of the backbone (*a b*). *c* is the breastbone (*sternum*). The ribs are joined to the breastbone by *cartilages* as at *d*.

The chest or thorax (*b* in Fig. 275) contains the heart (*h*) and lungs (*l*) and the windpipe that connects the mouth and nose with the lungs. The breath goes through the windpipe,[1] or *tra'chea*.

[1] The pupil should point out the different parts of the picture with a pin.

The abdomen contains the stomach (which is connected with the mouth by the gullet), liver, intestines (or bowels), etc.

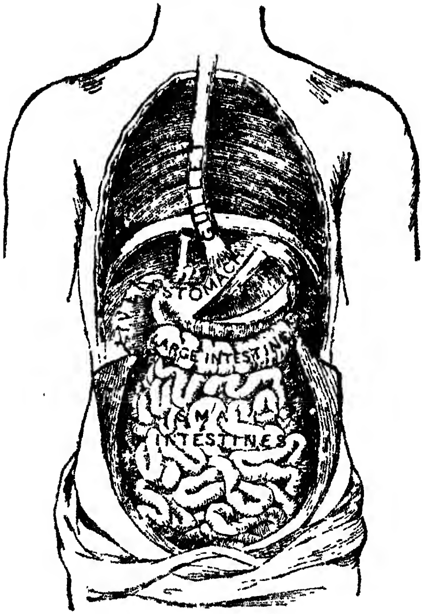


FIG. 278. The contents of the lower part of the ventral cavity —the abdomen.

Put your finger at the bottom of your neck and move it downwards, feeling for bones. When you feel no more bones you have reached the bottom of the chest (or thorax). Below that is the ab′domen. The food we eat passes through the gullet to the stomach, is there digested, and the useless remainder is got rid of through the intestine.

Organs of the Human Body.—The organs of the body are its separate parts that do special kinds of work. The heart is the organ that pumps blood through the body; the lung is the organ that breathes; the stomach is the organ that digests food; the ear is the organ by which we hear, and so on.

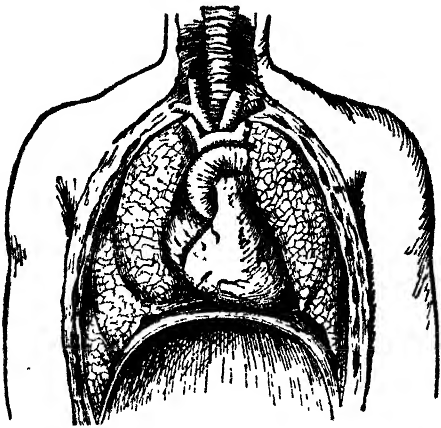


FIG. 279 The human body opened from the front so as to show the contents of the upper part of the ventral cavity. The windpipe comes down from the mouth to the lungs, which lie on both sides of the body. The heart is shown like a bag near the center. The upper part of the ventral cavity is separated from the lower part by the diaphragm, which is a stout membrane, or skin.

What the Body is Made Of.—The outside of the body is covered with skin. If the skin were taken off we should find *fat* below it. Under the fat, in the ball of the thumb, for instance, we should find red flesh, like the *lean* part of beef. This red flesh is *muscle*. The *skeleton* of hard *bones* (see Fig. 274) holds the body together and keeps it upright. Where the ends of joints come together, as in the fingers, for instance, we should find gristle, or *cartilage*. Besides all these things there are various kinds of tissues—stringy networks of fibers.

Connective tissue is tough and binds the different parts of the body together; *muscle tissue* is tough and strong and makes the muscles; *cartilage tissue* makes the gristle; *bony tissue* is stiffer and makes the bones. *Saliva*, or spittle, is in the mouth, *blood* in the arteries and veins, etc.

Chemistry of the Body.— If the trunk of a tree be burned part goes off in gases and part remains as ashes. If a human body be burned part goes off as gas and part remains as solid ash. Chemists have examined all the substances in the human body and have found that its principal *elements* are Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), Sulphur (S), Lime (Ca). These are combined into chemical compounds. Much of the body (of the blood, for instance) consists of water (OH_2); a good part of the bones is lime (Ca), etc.

The Human Skeleton: Bones. — A very young baby has a skeleton but its bones are soft like gristle. As it gets older the bones grow to be stiffer and stronger. Between the joints cartilage is found, and the bones are joined together by connective tissue. There are 206 different bones in the human skeleton. The most important are named in Fig. 274.

The pupil should turn to this page and point out, with a pin, on the picture, the principal bones of the body.

Cartilage.—The end of your nose is cartilage and can be bent. It is elastic. The upper part is bone and cannot be bent. (Try it.)

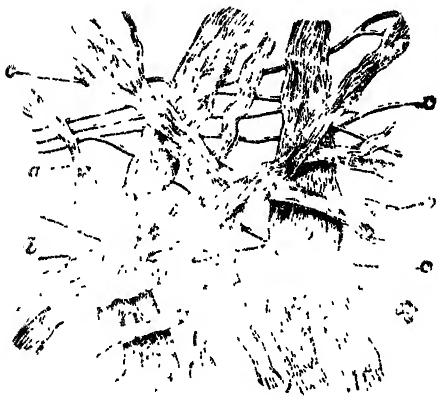


FIG. 280. Bundles of connective tissue such as bind the skin to the body. The tissues that bind the bones together and those between the muscles are of pretty much the same kind.

Connective Tissue.—If you watch the cook cut up a piece of suet you will see all through the mass a lot of tough strong fibers. She takes it out because it will not melt in cooking. Connective tissue in the body sometimes forms *ligaments* to bind the bones together, sometimes *membranes* (a kind of skin) that wraps and supports different parts.

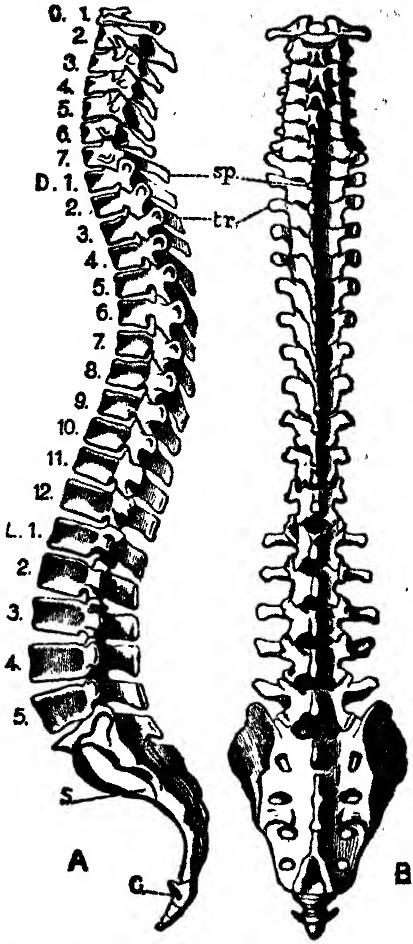


FIG. 281. Side view (*A*) and back view (*B*) of a man's backbone. He has seven vertebræ in his neck (*C* 1, 2, 3, 4, 5, 6, 7); twelve in his back (*D* 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12); five in his loins (*L* 1, 2, 3, 4, 5); *S* is the *sacrum*, *C*, the *coccyx* (like the beginning of a tail). Notice how each piece in the back view (*B*) matches a piece in the side view (*A*). You can feel the different pieces in your own body. (p. 296)

The Backbone (vertebral column).

Figure 281 shows the way the bones stand in a human backbone. Between each pair of *vertebræ* there is a little elastic cushion of gristle. If there

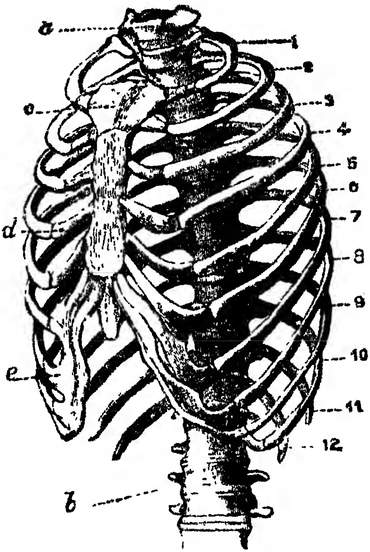


FIG. 282. The way the 24 ribs are joined to the backbone. The bony ends of 20 ribs are joined to the breastbone by cartilages like gristle.

were no gristle, if your backbone were stiff, you could not bend your body at all. Throughout the column runs the spinal cord, like the marrow in a bone, and it joins on to the bottom part of the brain in the skull.

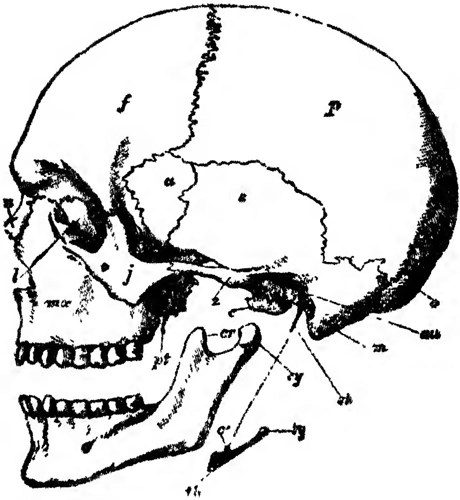


FIG. 283. A side view of a human skull. *f* is the *frontal* bone; *p*, the *pari'etal* bone, *o*, the *occi'pital* bone; *au* is the opening to the ear; *cr* is the place where the muscles of the lower jaw are fastened. The crinkled lines between the bones of the upper skull are called *sutures*. They are dove-tailed so as to be strong Carpenters make the ends of bureau drawers in the same way for the same reason.

The skull is shaped like a dome so as to be strong to protect the brain. Try to crush an egg-shell between your fingers. Although it is so thin and brittle, its dome-like shape makes it strong. The brain is the most delicate part of an animal's body. If it is injured, its mind will not work. And that is the reason why it is a great advantage to any animal to have its brain well protected.

A bone in the human body is covered closely with a kind of skin or tissue. The tissue or cover-

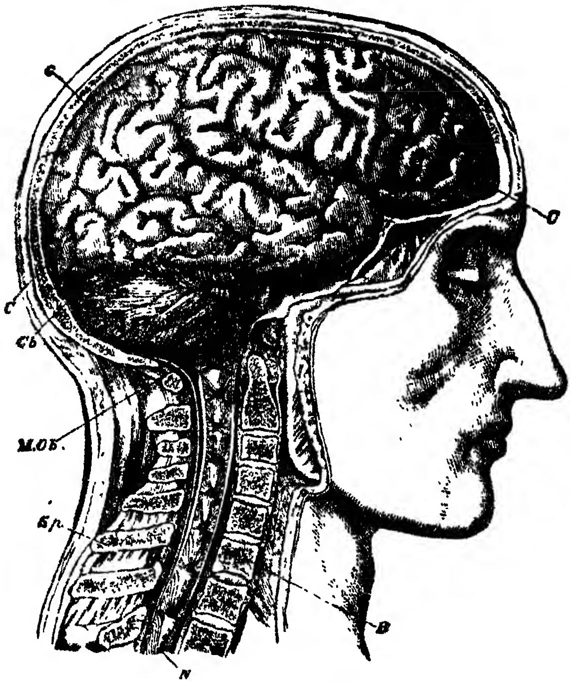


FIG. 284. How the brain (*cc*) is protected by the skull; and how it is joined to the spinal cord (*N*). Notice how far up into the head the backbone goes to support it.

ing is full of blood, and this blood feeds the bone and keeps it alive. If, by an accident, the covering is stripped off the bone it will not grow any more.

The Soft Bones of Children are Easily Bent out of Shape. — The bones of babies are like gristle; the bones of children are much softer than those of grown-up people. It is therefore important that children should be taught to stand erect, to walk properly, to sit correctly, and that they should not wear too tight-fitting clothes or shoes.

A very young child that is allowed to walk before its legs are strong enough may become bow-legged; a school-child that sits on a bench so high that its feet cannot touch the floor may have the bones of the upper leg permanently curved; children who loll at their desks may get a bad curve to their backbones; children who wear tight shoes will get crooked feet. A girl that wears stays that are too tight compresses the lower ribs so that there is not room enough for healthy organs and they will become more unhealthy as she grows older.

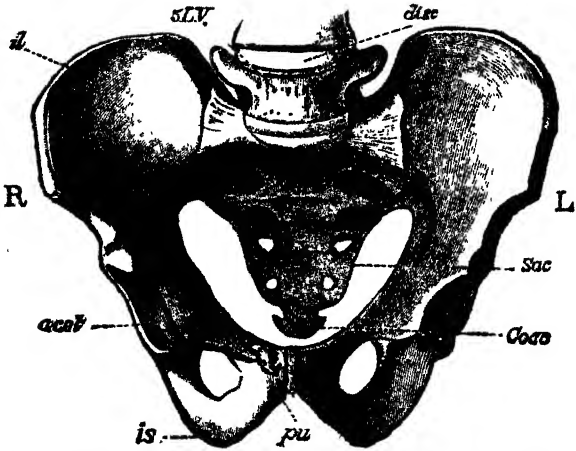


FIG. 285. Front view of the bones of the hips. The lower end of the backbone is at the top of the picture. Then comes a cushion of gristle marked *disc*, then the lowest of the vertebræ of the back (5 *L. V.*), then the sacrum (*sac*) and the coccyx (*cocc*) (compare this picture with Fig. 281). The upper bone of the leg fits into the place marked *acet*—there is one such place for each leg. *R* is the person's right hand side, *L* the left hand. All these bones together make a ring which is called the pelvis,

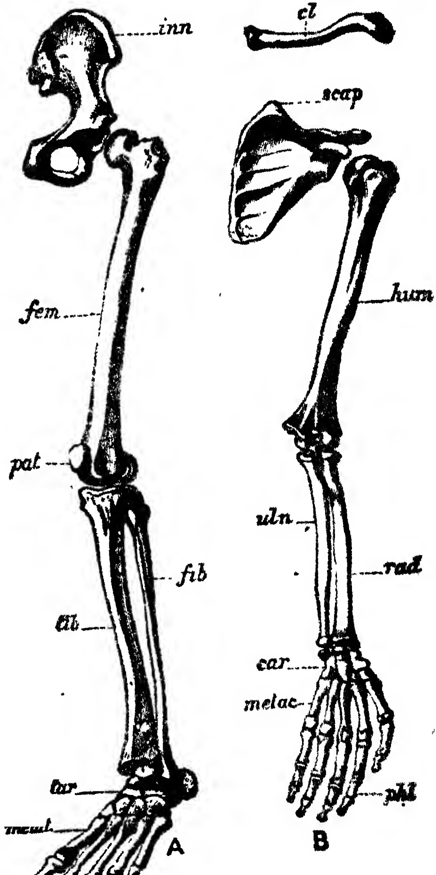


FIG. 286. Front view of a man's left leg (*A*) and left arm (*B*). Take the arm first (*B*): *cl* is the collar-bone (*clavicle*); *scap* is the shoulder-blade (*scapula*); *hum* is the bone of the upper arm (*humerus*); *rad* and *uln* are the two bones of the lower arm (*radius* and *ulna*); *car* is the place of eight bones of the wrist (*carpal bones*); *metac* is the place of five bones of the hand (*metacarpal bones*); *phl* are the finger-bones (*phalanges*). Take the leg next (*A*): *inn* in this picture is the same as the hip-bone marked *L* in the last picture (compare the two), *fem* is the bone of the upper leg (*femur*); *pat* is the knee-cap (*patella*); *tib* and *fib* are the two bones of the lower leg (*tibia* and *fibula*): *tar* is the place of the seven bones of the ankle and heel (*tarsal bones*); *metat* is the place of the five bones of the foot (*metatarsal bones*); *phl* are the toe-bones (*phalanges*).
You can easily discover many of these bones in yourself by feeling your own arm and leg. (Try it.)

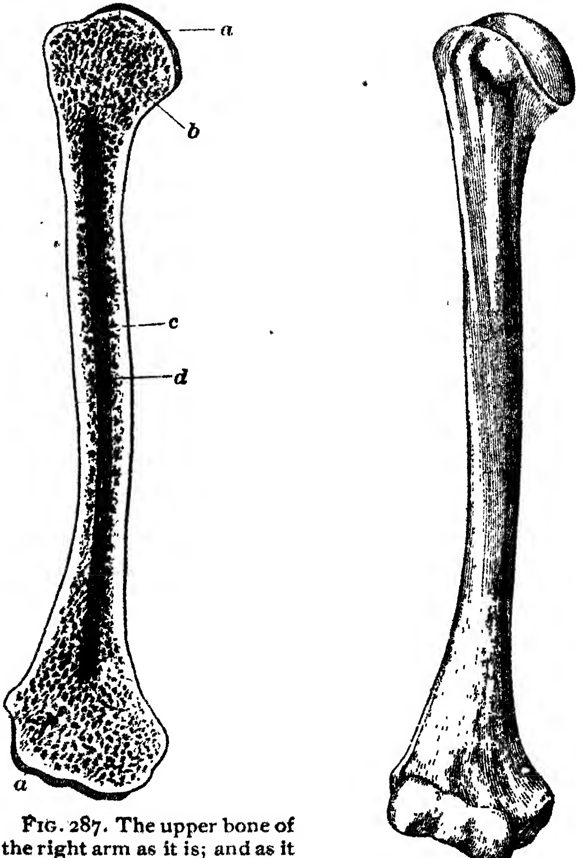


FIG. 287. The upper bone of the right arm as it is; and as it would look if sawed down the middle. The upper end of the *humerus* fits into the shoulder-blade (see Fig. 286). The lower end forms part of the elbow. The joints are oiled with a fluid like oil. The bone is hollow and the hollow is filled with marrow. Round this is the spongy bone *b* and *c*; and outside is the hard bone. At the ends are two pieces of gristle *a*, *a*. Split the bone of a chicken's leg and you will see how bones are built. (Try it.)

The Bones of the Arm, with the Biceps Muscle.

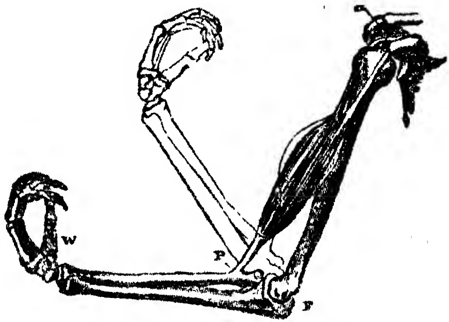


FIG. 288. The bones of the arm, with the biceps muscle. By comparing this picture with Fig. 286 you can see how the muscle of your upper arm is fastened to the shoulder-blade by two *tendons* at (*a*). The lower end of the biceps muscle is fastened to the radius bone of the lower arm at *P*. *F* is the elbow. By willing to do so, you can make the biceps swell up and shorten (the thin lines show its outline then) and thus raise your hand to the place shown in the middle of the picture. Put one hand on your biceps and raise your lower arm as in the picture, and you can feel the biceps grow larger and shorten. Muscles move the bones they are fastened to when they shorten. Muscles shorten when you *will* that they should do so.

It is Worth While to Keep Our Bodies Healthy. —Children usually feel pretty well and think very little about good health or bad health. But if they will look around them they will see that the world is full of older people who are not well. Every one of those people is less strong, less useful, and less happy than he or she ought to be. How would *you* like to be ill and in pain for half of your life? By eating the right kind of food in the right way, by not eating the wrong kind of food at all, by not smoking tobacco and by not drinking alcoholic drinks, by standing, walking and sitting straight, by wearing the right kind of clothes and shoes, by keeping your body clean by baths, and strong by regular exercise, you can keep yourself healthy.

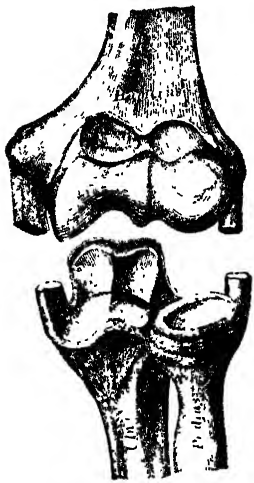


FIG. 289. The elbow-joint—separated. Projections on the bone of the upper arm (*humerus*) fit into cups at the upper ends of the two bones of the lower arm (*ulna*, *radius*). The bones are joined by ligaments (two of them are shown cut apart in the picture). Hold your arm straight out and turn your lower arm round so that the back of your hand is first up, and then down.

If your body is healthy and your mind is healthy too, you will be able to live a useful and a happy life. This is worth while. Think about it. At least half the misery in the world comes because children have neglected the very simple laws of health during the years when their bodies were growing and developing. Begin *now* to form good habits which will keep you healthy and happy all your life.

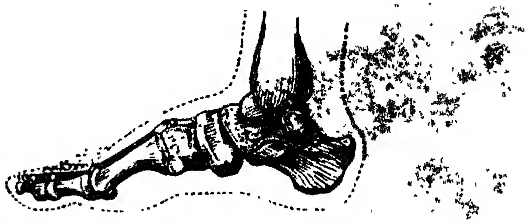


FIG. 290. The bones of the right foot. Notice that the foot rests on two points; on the heel and on the ball of the foot. Between those points there is an arch (the instep) which is elastic. That is why you walk with a springy step. If there were no elastic arch you would feel a jar in your brain every time you planted your foot in walking.

Moreover, if you will look about you, you will see that many older persons who seem, on the whole, healthy enough, are yet not very useful, not very successful, and on the whole not very happy. In very many cases they are less useful and less successful because in the struggle for life they are handicapped and hindered by a poor digestion, headaches, nervousness or something of the kind. Our opportunities for usefulness or success come unexpectedly and do not wait upon our convenience. They come suddenly and do not wait long. The man who is in good health can seize them as they fly. The man who has headaches, who is too fat, or too tired, lets the fortunate moment pass. He does not succeed; he is not useful. Many battles have been lost because the Generals were not in perfectly good condition and health. They could not think quickly and correctly. Life is, in some ways, like a battle. The soldier who keeps his

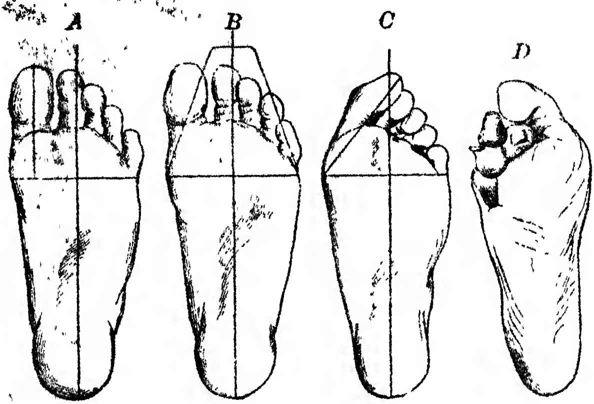


FIG. 291. The human foot is naturally like *A* or *B* in the picture. A narrow-toed shoe, of the shape of the outline in *B*, will cramp the toes as in *C* or *D*.

body and mind in good health is the one who succeeds. Healthy minds usually live in healthy bodies.

The Teeth.—Babies begin to cut their *milk-teeth* when they are about six months old, and by their second year they have twenty teeth. The *permanent teeth* begin to grow when the child is six years old. They take the places of the milk-teeth. The last teeth (four "wisdom-teeth") are cut at about twenty-two years. By that time a person is expected to know something. If a tooth of the second set is lost, by being broken, or decayed, no new tooth will come to take its place. Therefore, *be careful of your teeth.*

Go to a dentist at least twice a year and have your teeth examined. Do not abuse them by cracking nuts with them, or by drinking very sour (acid) drinks, or by eating very hot foods. Brush your teeth twice daily with a moderately stiff brush using white castile soap and powdered chalk. Use a quill or a wooden toothpick frequently to remove particles of food lying between the teeth. Never use metal toothpicks like needles, pins, etc.

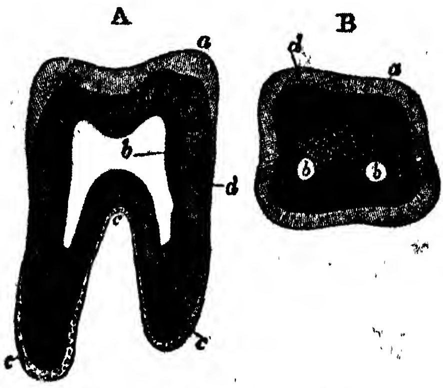


FIG. 292. The left-hand cut (*A*) shows a tooth sliced in two up and down; (*B*) shows the same tooth sliced crosswise. Both pictures are just three times as large as life. In both pictures *a* is the very hard *enamel* of the outside of the tooth, *d* is the hard *dentine* or bone, *b* is the space filled by the *pulp*. The pulp is a soft, red, very sensitive core, full of blood and nerves, and is the part of the tooth that is most alive. Through its blood the rest of the tooth is fed. (It is often called *the nerve.*)

Muscles.—The muscles of our body make it possible for us to move, to walk or to stand erect; for

FIG. 293. The outer muscles of the body. If the skin of a man were transparent you would see his muscles as in the picture. Beneath the muscles shown here there are hundreds of others. The picture shows only the outer layer. Compare this picture with the next one and trace out, with a pin, the muscles of the shin, the thigh, the abdomen, the back, the neck, the arm.

our heart to keep beating, for our lungs to breathe, for our stomachs to digest our food.

We breathe and our hearts beat whether we *will* to have it so, or not. The muscles that do this sort of work are called *involuntary muscles* (that is muscles that work independently of our wills). You cannot make your heart stop beating. (Try it.) You can hold your breath a long time, but not forever. (Try it.) We move our arms and legs by another kind of muscles which do their work when we *will* them to do it — voluntary muscles. You *will* to move your arm first; and then your arm moves.

When a gorilla—whose skeleton is very much like that of a man (see Fig. 273)—is walking, he rests his fists on the ground and goes on all fours nearly all the time. A man walks upright and his two hands are free. Thus a man, even if you think of him as an animal and nothing else, has a great advantage over any other animal. Man is the only "tool-using animal" partly because his two hands are free to use the tools; partly because his intelligence is sharp enough to invent the tools in the first place.

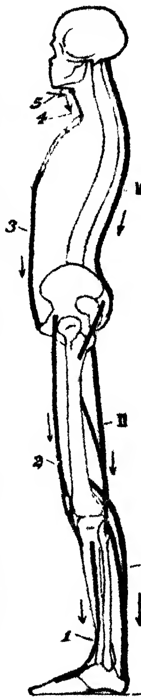


FIG. 294. A sketch to show where some of the most important muscles are: (I.) the muscles of the calf of the leg; (II.) the muscles of the back of the thigh; (III.) the muscles of the backbone (these keep the body from falling forward); (1) the muscles of the front of the leg; (2) those of the front of the thigh; (3) those of the abdomen; (4, 5) those of the neck. When you are standing still all these muscles are at work to keep you upright. The pull, the force, acts along each muscle in the direction of the arrows.

Tendons.—The middle of a muscle is usually a red soft swollen part (like the biceps of your upper arm—Fig. 288) connected by tendons—tough white cords—with the parts that are to be moved. You can easily find the tendons that bend your fingers by feeling for them on the inside of your wrist.

Muscles Can be Educated and Can Get Habits.—A baby has to *learn* to stand. Each muscle has to be *taught*. By and-by the muscles learn just how they must act and each muscle acquires a *habit*. After that the child can stand without thinking how standing is done. Swimming, bicycling, riding on horseback, have to be *learned*. The proper muscles have to acquire *habits*. After that, we can swim or ride on bicycles without thinking. When you are first learning to ride a wheel your brain has to think every minute about what you are doing. After you have learned, you can ride along and think about something else. All your muscles have acquired their habits, and your brain is free from responsibility. Your breathing is done, for instance, without any thought of yours.

Contraction of Muscles.—A muscle does its work by contracting—by getting shorter. If the biceps muscle in your upper arm were a stout rubber band that would get shorter whenever you said "Now" and longer when you said "Enough" such a rubber band would do the work that is wanted. A rubber band would not get tired, but muscles do get tired in time. Then they must rest until enough new blood has been poured into them. They are like willing laborers; but every now and then a laborer must stop for food and for rest.

The Skin.—The skin is the tough outer covering of the whole body. It is like an India-rubber bag fitting loosely over the fat and muscles underneath. You can see that it is not tightly fixed to them by pinching up a fold of skin on the back of your hand and rolling it to and fro. Directly underneath the skin is a layer of fat, and under the fat are the muscles.

The Dermis and Epidermis.—The skin is made in two layers very close together. The outer layer, the one that you see, is the *epidermis* (sometimes called the *cuticle*). The inner layer is the *dermis* or the true skin. The outer skin is thin, horny, almost transparent, without blood-vessels or nerves, and is a protection to the sensitive skin underneath. If there were no outer layer to protect the inner skin, the whole body would feel like the "raw" skin at the bottom of a blister.

You can run a needle under the skin on the palm of your hand without hurting yourself, or without bringing blood, if you are careful not to go too deep (try it). The moment the needle enters the true skin underneath it touches a little vein, and blood flows; and it touches a nerve and you feel pain. Nerves are connected with the brain and telegraph a message there the moment they are touched. The *dermis* is alive and is all the while fed by the blood; the outer horny skin is, in great part, dead, and is all the while being worn off. After a hot bath a great deal of the outer skin can be rubbed off with a towel. A sunburned nose loses its outer covering of skin which peels off. The same thing happens after scarlet fever or measles. The outer skin peels off.

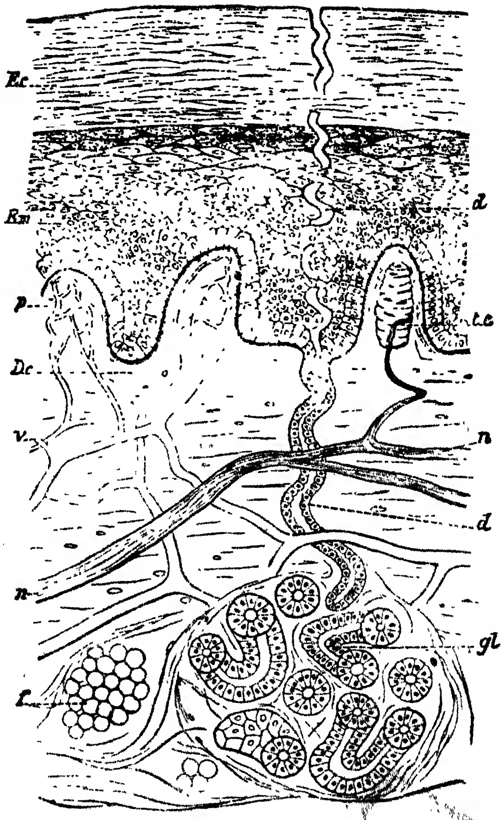


FIG. 295. How a piece of skin would look if it were sliced through and very much magnified.

The skin is about a tenth of an inch thick (of different thicknesses in different parts of the body). On the outside of it is *cuticle* or horny skin—*Ec* in the picture. This layer is dead and is continually being worn away. Underneath it is a layer, *Em*, of live cells from which new outer skin is continually being built up. All the rest is the *dermis*—true skin. It is full of veins carrying blood—*v* in the picture (trace out the veins in the picture with a pin). It is full of nerves, too—*nn* in the picture. Trace out the course of this nerve and you see it branches into a little coil *tc*. It is by little coils like this, joined to nerves, that you are able to feel when you touch anything; *gl* is one of the *sweat-glands* in your skin and it is connected with the outer parts by a tube, *dd* (trace it out)

The Organs of Touch. — Throughout the skin there are little coils joined to the nerves (*tc*, in the last picture). When the skin above one of these is touched, the nerve telegraphs to the brain "I am touched." If you take a pencil in your hand it touches a long row of such coils . . . . Each one of the row telegraphs to the brain and your brain (somehow) knows the shape of the pencil even when your eyes are shut. (Try it.)

If you press a postage stamp on your hand it touches a lot of coils arranged this way:

. . . . each one of these coils tele- : : : : : graphs to the brain "I am touched," . . . . . . and the brain (somehow) knows the shape of the thing that is touching. Not only does the brain know the *shape* in this way, but it learns something about the *hardness*. A copper cent feels differently from a round piece of cardboard of the same size (try it with your eyes shut). A warm cent feels differently from a cold one, too. The brain learns something about the *temperature* in this way, also.

Some Parts of Your Body are More Sensitive than Others.— Take two lead pencils sharpened to dull points and hold them close together, side by side. Have one of your companions close his eyes and do you touch the back of his hand or the top of his tongue gently with both points at once. He will tell you that two things are touching him. Now touch him with both points on the back of his arm, or on his shoulder-blade. He will tell you that only one point is touching him. (Try this experiment and others of the same kind, using sometimes one point, sometimes two; and putting the points sometimes close together, sometimes an inch or more apart.) Some parts of the body have a great many sensitive spots on every square inch (the tongue, the cheeks, the hands); some have only a few (the backs of the arms, the shoulders, the feet). The more of the spots there are, the more sensitive the body is to touch.

Sweat-glands.—Just as the leaf of a tree is full of pores, so the skin is full of little holes through which sweat, or perspiration, escapes. See Fig. 295, *gl* and *dd*. There are about 3,000 such sweat-glands to every square inch of the palm of your hand and about two millions and a half (2,500,000) in the whole body. Look at the palm of your hand with a common magnifying glass and you can see the holes at the ends of the sweat-gland tubes. The little tubes leading to the glands are about ¼ of an inch long, so that in the whole body there are about ten miles of them.

The Chief Use of the Sweat-glands is to Keep the Body at the Right Temperature.—It is a fact that the temperature of the body of a healthy man is about 98° Fahrenheit, no matter whether he is in the cold arctic regions, or in the burning deserts of Arizona. If his temperature falls a few degrees he dies; if it rises a few degrees he dies. The sweat-glands regulate his temperature. When the body is very cold there is almost no sweat; when it is very hot there is abundance of perspiration which collects in drops on the skin. There it evaporates into the air as (invisible) water-vapor and in evaporating it makes the body cooler. (All evaporation cools the air.) It is in damp weather, when the perspiration evaporates very slowly (because the air is already full of water-vapor) that you feel the hottest. Hot, dry weather is far less trying. If the whole body is kept clean by daily baths the sweat-glands will work well and will be healthy.

The Complexion.—Deep down in the little cells that make the *dermis* there are grains of coloring matter like a paint. In blonde persons there is only a little of it and we say they have pale faces. Brunettes have more, and we say their complexions are dark. Negroes have a great deal. When the skin is much exposed to sunlight more of this coloring matter is formed and the skin is "tanned," as we say. If the true skin is burned by a deep burn the coloring matter is all destroyed, no more grows and therefore scars, even on negroes, are white.

Blushing.—Sometimes there is a rush of blood to the *dermis* underlying the cheeks that brings a blush. It is curious that our arms or shoulders do not blush. They are usually covered, and blushing there would not be a sign to others that we were ashamed or angry. Blushes come to the cheeks where they can be seen, just as flowers have gay petals in the places where they are of some use.

Finger-nails and toe-nails are made from the outer layer of the skin, but they are fed by the true skin (*dermis*) at their roots. The claws of animals correspond to our finger and toe-nails.

FIG. 296. A slice of the skin—much magnified—showing the way hairs grow on the body: *a* is the outer layer of horny skin; *d* is the inner layer of skin. Two hairs are shown growing in two little sheaths. The oil that makes the hair glossy comes from two *oil-glands* (*e*) half way up the root of each hair. The roots of the hairs are close to nerves. When a hair is pulled out you feel a little pain. When anything touches the end of a hair you know it, just as a cat knows when anything touches the ends of her whiskers. (Try touching the hairs on the back of your hand.)

Hairs.—The bodies of many animals are covered with thick fur. Our bodies — except the palms of the hands and the soles of the feet — are covered with a scanty growth of fine hairs (look at the back of your hand) and long and thick hair grows on our heads.

Food and How it is Used in the Body. — The body is a machine for doing work, somewhat as the steam-engine is a machine for doing work. In the steam-engine we must have fuel that is burned and from the burning we get power. In the body we must have food that is oxidized (that is burned) and from the food our bodies get power.[1] When a steam-engine gets out of order, it cannot mend itself, but our bodies can and do mend themselves

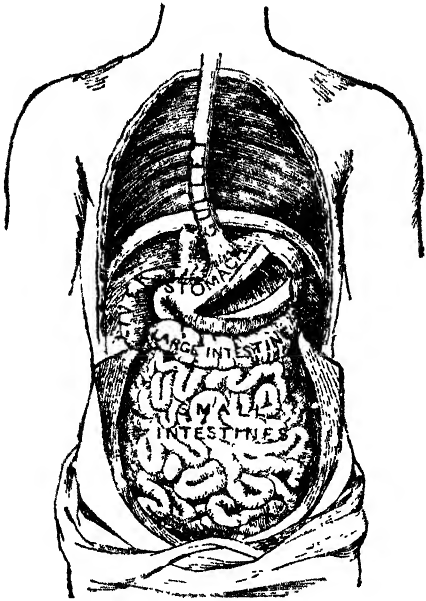


FIG. 297 The stomach and intestines. In the picture the stomach is slit open to show its interior

[1] The work that a man's body does is partly external, partly internal. The external work can be measured in foot-pounds (the energy required to lift one pound one foot is a foot-pound). A healthy man can do about 2,000,000 foot-pounds of external work per day, that is he can lift about 2,000,000 pounds one foot high, lifting a few pounds at a time and keeping at it. His internal work keeps his heart beating, his lungs breathing, his body at its temperature of 98° Fahr., etc., and amounts to about 5,000,000 foot-pounds daily.

in many cases. For instance, if your arm is badly burned and loses its power, your blood will bring the food necessary to make it well and strong again.

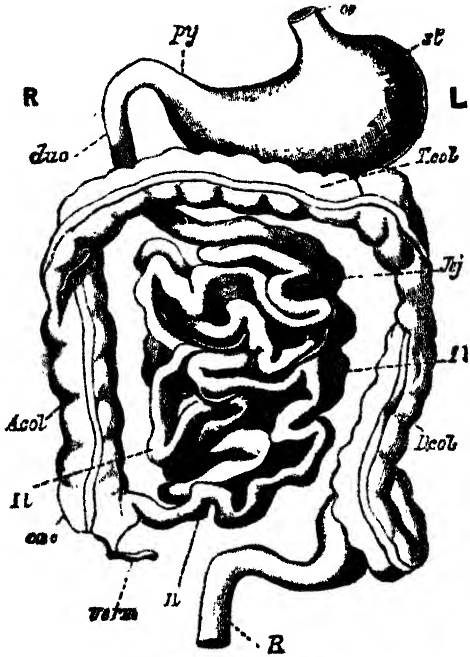


FIG. 298. The stomach, the large intestine, the small intestine (seen from the front) : *st* is the stomach ; *Il*, the small intestine ; *A col*, *T col*, *D col*, the large intestine ; *verm* is the appendix.

Food taken into the mouth is chewed and then swallowed. It goes through the gullet into the stomach. There it is dissolved by the *gastric-juice* and made into a soft mass, like very thick soup, called *chyme*. This is mixed with *bile* from the liver, and with other fluids, and passes into the small intestine where it is turned into a cream-like liquid called *chyle*.

Now at last the food is ready to be taken into the blood. The undigested and useless parts are passed along the bowels and finally ejected.

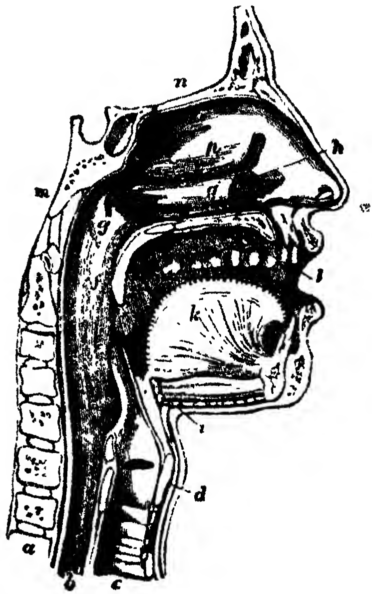


FIG. 299. The throat sliced down the middle: *b* is the gullet; *l*, the roof of the mouth; *c*, the windpipe; *k*, the tongue; *e* is a little lid which shuts down over the windpipe when you swallow so that food cannot go down "the wrong way." Put your fingers on the Adam's apple of the throat outside, and pretend to swallow. You can feel how the little lid closes the windpipe.

Digestion in the Mouth.—If the food is well chewed there is a good supply of *saliva* (spittle) in the mouth. The mouth and gullet are lined with a soft red skin called the *mucous membrane*. (You can see part of it by standing in front of a mirror with your mouth wide open). The *saliva* moistens the food and gets it ready to be swallowed. You could not swallow a cracker— which would be mere dust—unless it were first moistened.

The smell of food, or even the thought of it, makes the *saliva* flow. "It makes your mouth water," we say.

Food Passes Down the Gullet Slowly.—It does not fall down as a brick falls down a chimney. The gullet is a small tube full of rings of muscle which seize the bits of food and move them along from ring to ring. Horses drink with their heads lower than their stomachs by this means. The water they drink is made to flow up-hill.

Gastric Juice.—The moment food enters the stomach gastric juice trickles out, somewhat as sweat on the skin, and begins to digest the food.

A Canadian hunter was accidentally shot so that the bullet left a hole from his abdomen into the stomach. His doctor was able to see exactly how digestion went on by experiments made through this wound.

After a time, sometimes one hour, sometimes as much as four hours, the *chyme* of the stomach begins to move into the small intestine. Usually the stomach is entirely emptied about three or four hours after a meal.

Digestion in the Stomach.

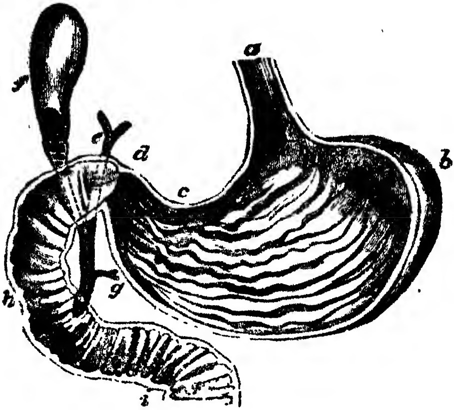


FIG. 300. The stomach sliced in two so as to show: *a*, the lower end of the gullet; *d*, the opening into the small intestine: *e*, the tube through which *bile* comes from the liver. The stomach is large enough to hold about four pints. Its walls are stout and muscular. Inside it is covered with a *mucous membrane* full of thousands of small glands that give out *gastric juice*.

Digestion in the Small Intestine.—The small intestine is coiled up in folds which, if extended, would be about 20 feet long. (See Fig. 298.) It takes up the *chyme* and passes it along by its rings of muscle. At the same time the *chyme* is changed into *chyle*—which is very nutritious and looks like cream. As the *chyle* passes along it is absorbed, sucked up, by thousands of small tubes. From some of these tubes the *chyle* goes into the blood at once. Other tubes take part of it, mix it with *lymph* and pour it into a large blood-vessel, ready for use in making new blood.

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Digestion.—Water taken into the mouth is ready to mix with the blood at once. Things like sugar and salt are ready to mix with the blood as soon as they are dissolved. Starchy foods, the lean part of meat, etc., have to be changed by the gastric juice into *chyme* and then again changed into *chyle*, before they are fit for food.

Absorption.—Some of the nutritive food is absorbed by the blood-vessels of the stomach and thus passes into the blood. Much more of it is sucked up from the blood-vessels of the small intestine; still more by its *lymph-vessels*. All the useful parts of the food finally get into the blood, are carried by the blood to the heart, and from the heart this rich blood is pumped all through the body. New blood is continually being made in this way, and old blood is continually being made richer. All parts of the body are continually fed with blood. Good blood and plenty of it is what keeps us alive and well.

The Circulation of the Blood.—The blood circulates. It moves through the body in every direction. The heart is a hollow muscle filled with blood. It beats, that is it contracts like the bulb of a syringe, and squeezes its blood outwards into the *arteries*. The arteries go all through the body. You cannot put the point of a fine needle into your flesh anywhere without touching an *artery* and drawing blood. From the fine ends of the arteries the blood goes into still finer tubes called the *capil-*

lary (hair-like) *tubes*. The flesh, everywhere, is nourished and fed by arterial blood (it is bright scarlet in color). Other *capillaries* are joined on to the *veins*. The arterial blood from which the rich nourishment has been taken is sucked in by

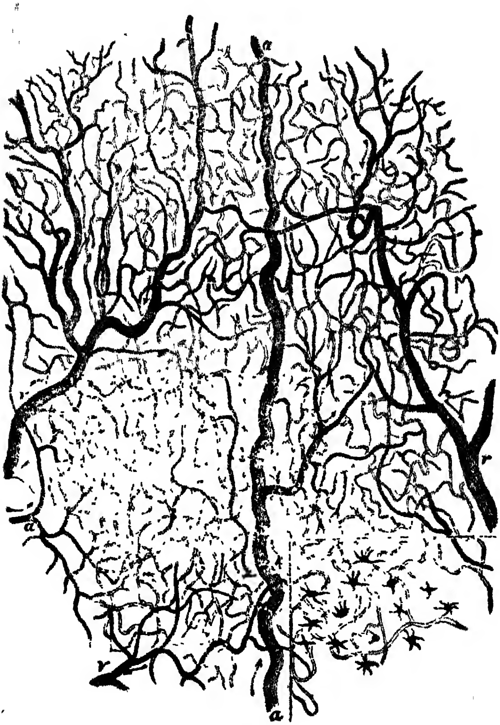


FIG. 301. The arteries (*a*, *a*) and veins (*v*, *v*) of the web between the toes of a frog, much magnified. The arrows (→) show which way the blood runs. All the smaller lines stand for the capillaries.

the capillaries, passed on to the veins (where it becomes dark red) and back to the heart again. In its course the blood passes through the lungs, too. Here it sucks in the *oxygen gas* of the air we have breathed. This oxygen makes the blood rich and nourishing again (and scarlet in color), and so the circulation goes on as long as you live.

Scarlet blood goes through the arteries and nourishes all parts of the body. After it has lost its oxygen it is of no use as food and must return to the lungs and to the heart to be made rich again.

There are so many thousand arteries, veins and capillaries that your whole body is made up of countless little islands, where no blood is, surrounded by rivers of blood flowing past them and making them rich and fertile (the arteries) or else taking away from them food that has been once used and is now useless (the veins).

The Heart.—(See Fig. 303.)

The Course of the Flow of Blood.—The blood starts from the left ventricle and flows into a large artery which soon divides into branches that lead all over the body. These branches end in the fine capillaries and when the rich blood has reached them it has done its work. It has brought nourishment to every part of the body. It has lost its oxygen and changed in color from scarlet to dull red. The fine network of veins collects the blood from the capillaries and draws it through larger and larger vein branches and finally pours it into the right auricle. From there it is pumped into the right ventricle and from there it goes to the lungs. Here it is again made rich by the oxygen of the air and is returned to the left auricle. From there it flows to the left ventricle and begins its circulation once more, and so on as long as you are alive. The blood flows through the whole body; this is the *systemic circulation*. It also flows through the lungs; this is the *pulmonary circulation*.

Experiment.—Bare your arm to above the elbow and let it hang down for half a minute. Its veins will be filled with blood. Now tie a bandage tight just above the elbow. The blood cannot get back to the heart fast enough and the veins will swell so that you can easily see where they are. (Try it—but do not keep the bandage on too long.)

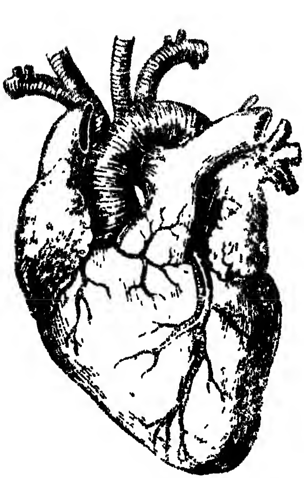


FIG. 302. The human heart, seen from the front. Your heart is about as large as your fist. See Fig. 279, page 293, which shows how it lies under the ribs.

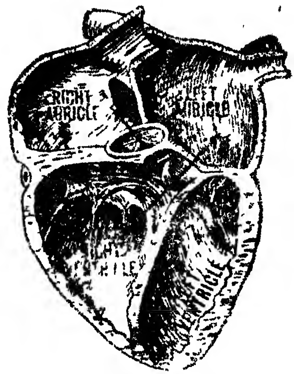


FIG. 303 The human heart sliced up and down to show its four cavities: (1) right auricle; (2) right ventricle; (3) left auricle; (4) left ventricle. The blood flows in the direction of the arrows because the valves of the heart (like trap-doors that will only open in one way) will not allow it to flow in any other directions.

Beating of the Heart; the Pulse.—The heart *beats* about 70 times a minute. Put your fingers on your wrist and count the number of beats in a minute.

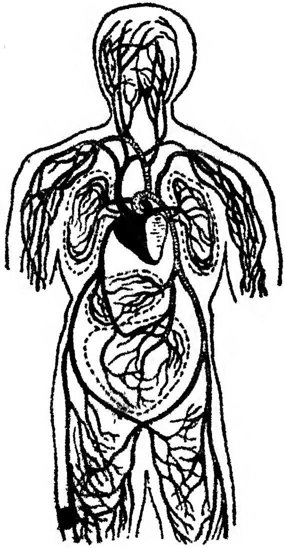


FIG. 304. The plan of the arteries and veins of the front part of the body. The arteries are black; the veins are drawn in dotted lines. (Trace out the arteries and veins with a pin for a pointer.) In the arteries the blood flows about 16 inches every second, and in the larger veins about 4 inches.

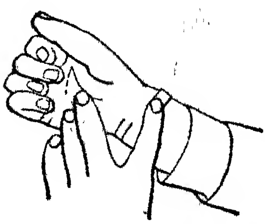


FIG. 305. An experiment to show the beating of the heart (the *pulse*) to a class. Bare the wrist and press a bit of looking-glass about half an inch square upon the wrist and hold it there steadily with one finger. Every time the pulse beats the mirror will move slightly. Let the direct rays of the sun fall on the mirror and be reflected to make a spot of light on the ceiling or wall. The motion of this spot will show the beat of the pulse, much magnified. (The teacher should show the scholars how to make this instructive experiment.)

The Blood.—The blood in a man's body weighs about twelve pounds. Blood, to the eye, looks like a red liquid. When it is seen through a microscope we find it to be a colorless liquid (the *blood-plasma*) in which float thousands of little solid particles. These are the *blood-corpuscles*. Most of them are red, but many are white.

Blood Corpuscles.—

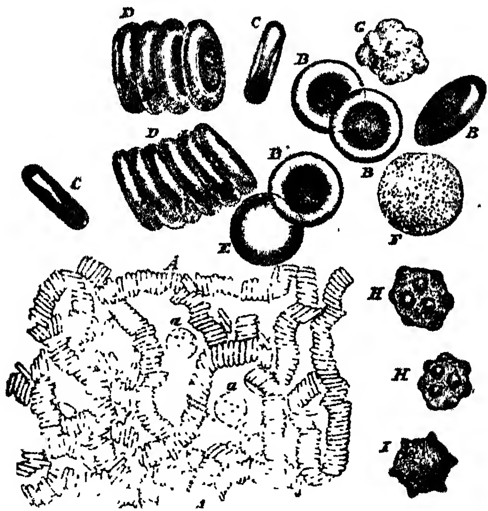


FIG. 306. Blood-corpuscles. (*A*) The picture between the letters *A* and *A* is not very much magnified. It shows the red corpuscles lying in strings like piles of copper cents, and two white corpuscles *a*, *a*. *B* shows two red corpuscles, much magnified, seen flatwise. *C* is a red corpuscle seen edgewise. *D* is a string of red corpuscles.

The red corpuscles are about $\frac{1}{3200}$ of an inch in diameter and about $\frac{1}{12400}$ of an inch thick. Ten millions of them will lie on a square inch, and the body is full of them. *The red corpuscles carry oxygen with them to all parts of the body, and keep it alive.* The white corpuscles of the blood are in form and in character like the single-celled animals called *Amœbæ*. When they meet a particle of blood that has no right to be there, they flow around it and absorb it, just as the Amœba flows around and absorbs its own food. As long as the red corpuscles of the blood are healthy they are not attacked, but the moment a red corpuscle is diseased, it is treated like an enemy. *Bacteria* (vegetable germs of some diseases—*microbes*, so called) are devoured by the white corpuscles, and the body protected from harm. During an illness due to poisoning of the blood by microbes—malaria, for instance—there are countless battles between the hostile microbes and the white corpuscles. If the latter win the fight the patient recovers. If the white corpuscles are defeated the patient dies.

Without Blood We Cannot Live.—If an artery is cut by an accident, the man will bleed to death. If blood from another person, or from a dog, is pumped into his veins he can be revived—made to live again.

Blood gets its nourishing food from digested food. It gets oxygen from the air we breath. (Air is a mixture of oxygen and nitrogen gas.) As the blood passes through the lungs it gives out carbonic acid gas and this is breathed out by the lungs at each breath.

We Speak by Air Forced Through the Glottis, and different sounds are heard according as the opening of the glottis is large or narrow. By much practice the muscles have learned just how wide to open the glottis to make the sound of A, or B, etc. Babies learning to speak have to think about the words they are going to say. We have said them so often that our muscles have learned their habits and work almost like machines, without much thinking from us.

The Air-Passages.—

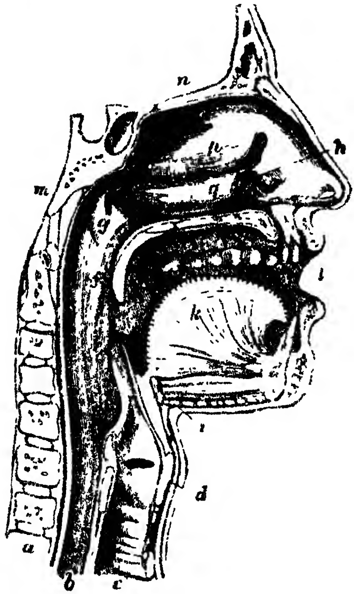


FIG. 307. The head sliced downward, nearly through the middle: *a* is the spine, *b* the gullet, *c* the *windpipe* (***trachea***) which carries air to the lungs. The *air-passages* are the ***pharynx*** (*g*, *f*, *e*) and the *larynx* (*d*) (the part of the same tube below *e*). The "Adam's apple" is at *d*: *e* is the *epiglottis*, a little lid or trap-door, which closes the windpipe when food is swallowed but leaves it open when you are speaking: *d* is a box of gristle in which there is a slit called the ***glottis***. The air passes through this slit when we speak, and we can make the slit wide or narrow, as we choose. When we breathe it is wide open. When we are speaking it is sometimes wide, sometimes narrow.

Take a hollow tube, like a piece of a bamboo fishing rod, about a foot long and cut the top of it sloping like a Λ. Wrap a piece of thin sheet rubber (such as dentists use) round the top so as to leave a narrow slit at the very top of the Λ, to stand for the opening of the *glottis*. Tie the rubber on with a string. Now blow through the lower end of the tube and you will get a sound. Touch the vibrating rubber at different points with the sharp end of a pencil and you will get different sounds. (Try it.)

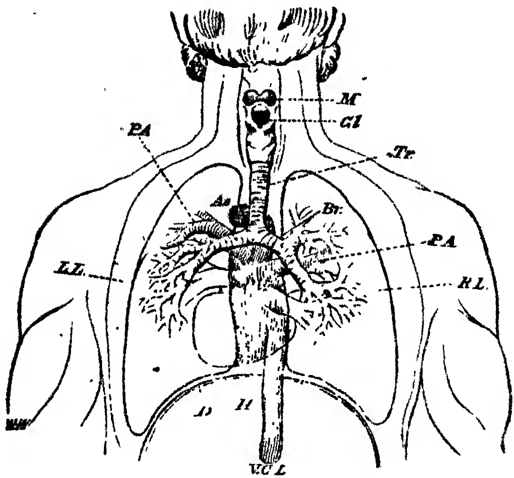


FIG. 308. Back view of the windpipe and lungs. In the picture the backbone is not shown. *M* is the mouth (seen from behind, as if the body were transparent); *Gl* is the *glottis* (part of the windpipe); *Tr* is the windpipe; *LL* is the left lung; *RL* is the right lung; *Br* (on both sides) are the *bronchial tubes* (the ends of the windpipe); *H* is the heart. (Point these parts out with a pin for a pointer.)

Breathing (***Respiration***).—We breathe air (which is a mixture of oxygen gas and nitrogen gas). It goes into the lungs through the ***bronchial***

tubes and mixes with the blood which takes out all the oxygen it needs. The used-up matters in the blood (mostly carbon) combine with some of the supply of oxygen and make carbonic acid gas. This poisonous gas we breathe *out* about 18 or 20 times a minute (oftener for children).

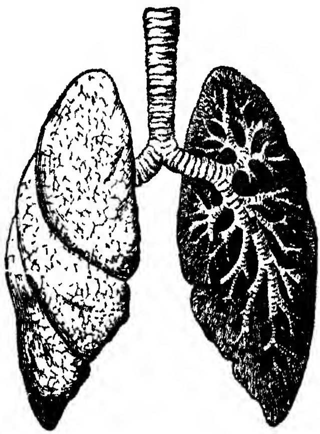


FIG. 309. The lungs and the branches of the bronchial tubes.

Experiment.—Take a very small piece of *quick lime* and drop it into a little water at the bottom of a good-sized jar. It will bubble fiercely and become hot (the water is combining with the lime). When it is cool filter a clear solution—lime-water—into a tumbler. Now let one of the pupils breathe into the lime-water through a clean glass tube. The water will become turbid. Why? Because the carbonic acid gas of the breath has combined chemically with the lime to form carbonate of lime which is insoluble in water. Let the water settle. Pour off the surplus, liquid, leaving only the semi-solid mass. Add vinegar. It will displace the carbonic acid gas which will go off in bubbles.

Movements of the Chest in Breathing.—

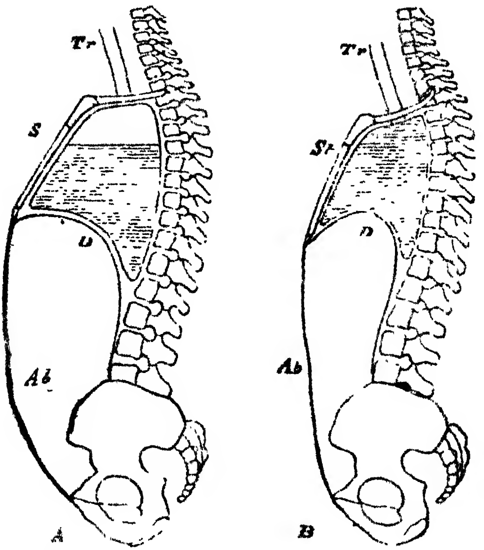


FIG. 310. *A* is a section of the body as air is breathed *in*. *B*, as air is breathed *out*. *Tr* is the windpipe, *D* is the diaphragm, *Ab* the muscular walls of the abdomen. The chest, abdomen, breastbone (*St*) and ribs move when you breathe.

Plenty of Fresh Air is Necessary to Life.—If there is not enough fresh air, the blood will not get enough oxygen and the body will starve. Many headaches come from lack of fresh air. Go out of doors and they will disappear.

Good ventilation is supplying plenty of air to the rooms in which we live—study-rooms, living-rooms, sleeping-rooms. Always have fresh air and plenty of it, and arrange the doors and windows so as not to make "draughts" of air blowing directly on you.

Sneezing and Coughing.—Draw a deep breath and fill the lungs, and then force out the air through your nose. (Try it.) Now let some one tickle the inside of your nostril with the fine end of a feather. You sneeze; you *have* to sneeze; you cannot help it. Filling the lungs full and then forcing the air through the nose, *when you cannot help doing so*, is sneezing. Coughing is forcing the air out through the mouth.

Breathe Through Your Nose, Not Through Your Mouth.—Keep your mouth shut when you breathe, even when you are running. Air that gets to the lungs should be warmed by passing through the passages of the nose, not taken in directly through the mouth, in which case it is likely to be too cold. The little hairs inside the nostril act as strainers, and catch dust that ought not to get into the lungs.

The nervous system consists of the Brain, the Spinal cord (or marrow) and a set of *nerves* spreading all over the body.

The brain is a complicated mass of very sensitive matter that fills the upper part of the skull. It weighs about 4 pounds. (A butcher will show you a sheep's brain if you ask him.) It has three main parts: the *cer'ebrum*, or large brain (in this part all the most important things we do are decided); the *cer'ebel'lum*, or lesser brain (this part arranges our motions so that our muscles work together in harmony). If this part is removed from a bird's skull it can still see, hear, eat and fly—but it cannot fly straight nor balance itself); the *medul'la* (this part tells the lungs when to breathe, the heart when to beat, the mouth when to swallow or to cough, etc. It manages the *involuntary muscles* (see page 309).

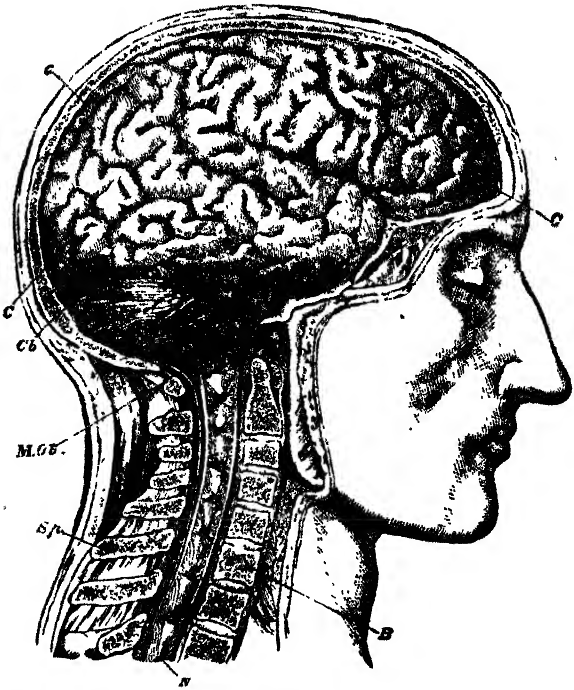


FIG. 311. Side view of the brain and upper part of the spinal cord. *CCC*, is the furrowed *cere'brum* or larger brain; *Cb*, the *cer'ebel'lum* or lesser brain; *M*, *Ob*, the *medulla oblongata*, a complex nerve-center; *N*, the *spinal cord* and its nerves.

The brain—somehow, no one knows exactly how—remembers what you have seen and heard,

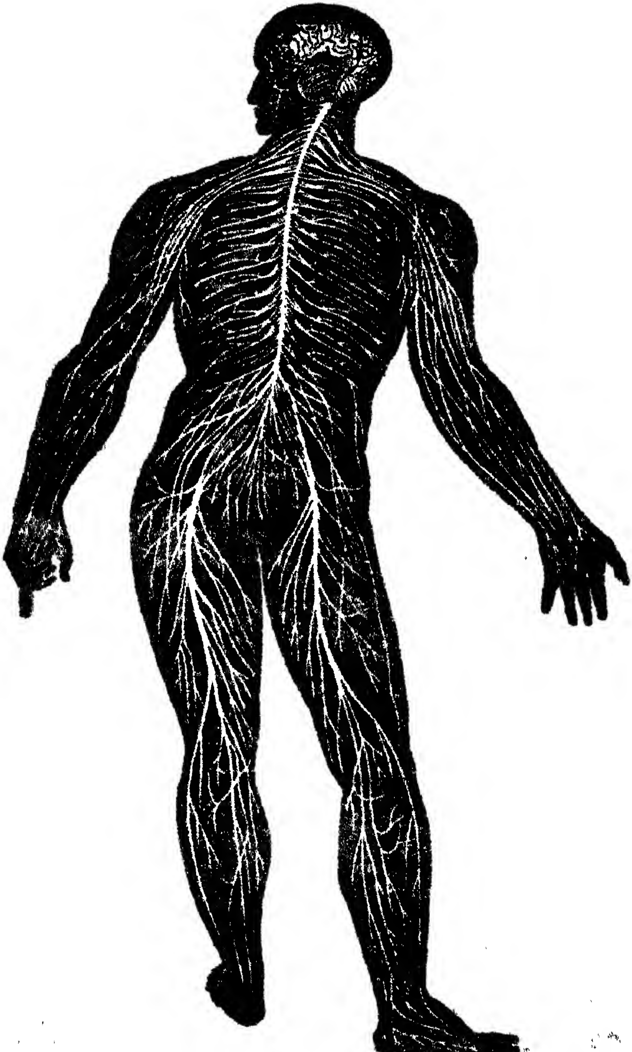


FIG. 312. The brain, the spinal cord, the nerves. (p. 335)

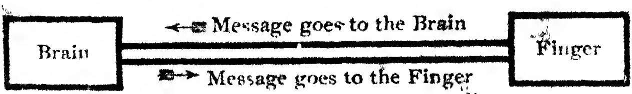
knows what you are seeing and hearing now, decides what is best to do now, and sends out orders through the *nerves* for the muscles to do it—and they obey.

The brain is connected with the spinal marrow, and nerves branch oft in every direction (very many more than are drawn in the picture).

The nerves are fine hollow tubes filled with something like clear jelly. They run all over the body as telegraph wires run from a central office.

The Nerves Carry Messages To and From the Brain.—The brain acts as if it were a central telegraph station. Some nerves, like telegraph wires, carry messages *inwards* to the brain, and others carry messages *outwards* from the brain. Suppose some one pricks your finger with a pin. The pin touches a nerve. This nerve carries a message to the brain and says "I am touched." The brain sends a message to the muscle of your finger along another nerve and says "move away." The muscle shortens and the finger moves away from the pin. All the most important bodily actions of men and animals are decided in this way.

This can be proved. We know exactly which nerve takes the message from the finger to the brain, and which nerve brings the order out. We can cut them with a knife, if we choose.



Suppose we cut the top nerve, and then prick the finger. The finger cannot send any message to the brain because its nerve is cut. The brain will know nothing about the pin-prick because it has received no message. It will send out no order. Or, suppose we leave the top nerve whole, and cut the lower one. Now prick the finger. The finger will send a message to the brain and say "I am touched." The brain will know it. It will try to send out a message "move away," but as the nerve is cut the message cannot go that way.

Paralysis.—All the nerves that are in the leg unite near the hip into three or four large cords which join the spinal cord near its lower end. If these nerves are accidentally broken at the ankle, the foot is *paralyzed*, it cannot feel or move. But the rest of the leg is all right. If these nerves are broken at the knee, the lower leg is paralyzed; the upper leg can still feel and move. If they are broken at the hip, the whole leg is paralyzed. If the nerves of the leg are not injured, but the spinal cord is wounded, all the body below the wound is paralyzed.

If a telegraph line from Omaha to Boston is cut beyond Albany, then Boston can get no message; if it is cut beyond Chicago, then Albany and Boston suffer; if it is cut between Omaha and Chicago, then no messages can be sent to any part of the line beyond the break.

N. B.—We do not purposely cut nerves to try such experiments, but men sometimes meet with accidents that cut their nerves in two. In all such cases the doctors have noticed just what has been described.

If the whole cerebrum is cut out of an animal, a frog for instance, all its intelligence and will goes. It remains alive, but it is a mere machine that breathes, whose heart beats, etc. It can no longer *choose* what it *likes* to do. If the frog's legs are touched it moves them (not because it wants to do so, but because it cannot help it—just as you cannot help sneezing when the inside of your nose is tickled).

Such movements are made when messages are sent out from the nerve-centers in the spinal-cord, which control the beating of the heart, breathing, coughing, sneezing and all actions that

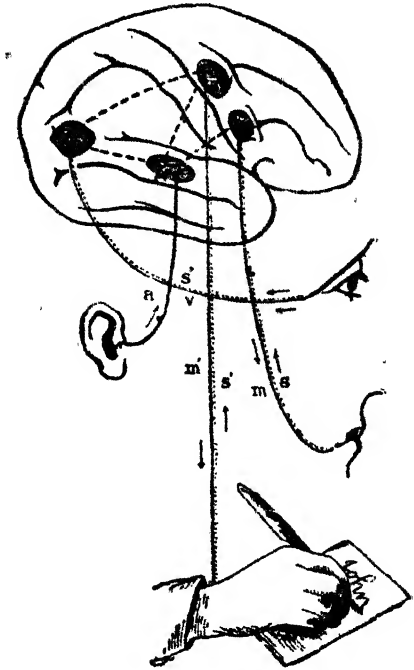


FIG. 313. A sketch to show how one set of nerves takes messages *to* certain centers in the brain, and how another set of nerves carries orders *from* these brain-centers *to* the mouth, the hand, etc. *V* (in the back part of the brain) is the center for seeing; *A* (connected with ear) is the center for hearing; *E* is the center for speaking; *W* is the center for moving the muscles of the hand in writing. If a sound comes to the ear a message is sent *in* to *A*. If a picture is seen by the eye a message is sent *in* to *V*. If you wish to speak a message is sent *out* from *E* to the lips. If you wish to write a message is sent *out* from *W* to the hand. It is as if the brain were the central telegraph office in which there are many operators at *V*, *W*, *A*, *E*, etc. When one of them receives a message coming *in* he tells the others what messages to send *out*. The messages are sent *out* and the hand or the leg or the lips obey the messages they receive. The messages come *in* along the nerves *s*, *s′*; they go *out* along the nerves *m*, *m′*.

must be done whether you will or no—*reflex-actions* as they are called. The *involuntary muscles* are controlled by centers in the spinal-cord.

Reflex-Action.—Experiment: Sit on a chair and cross your right leg over your left one. Now take a book and tap your right leg with it gently, just below the knee-cap. A short time after the tap your right leg will kick out, whether you will to do so or not. A set of nerves of the knee takes a message to the spinal cord (not to the brain), "I am struck." The spinal cord telegraphs back, "Kick then." The spinal-cord does all the work. The time between the tap on the knee and the kick is taken up by the two messages travelling two ways and by the action of the muscles of the leg. (Try it.)

Nerve Centers.—The nerve centers that control such movements as sneezing, etc., are in the spinal cord. Other parts of the brain are centers for seeing, centers for hearing, for speaking, for moving the hand, for moving the leg, for remembering, etc.

The different centers were discovered by noticing what happened when men's brains were injured by accident. If one part was injured, the man could not speak, though he could hear, see and move. If another part was injured, he could not move, though he could see, hear and speak. In this way it has been found that in certain tracts of the brain the powers of memory, of sight, of hearing, etc., reside.

How a particular spot in the brain makes us remember no one knows; but it is certainly so, for if this part of the brain is injured we cannot remember anything; as long as it is not injured, we can.

Sleep.—Plenty of sound sleep is necessary to give the brain rest. Children need about ten hours sleep. Seven or eight are needed by grown-up persons. During sleep the muscles rest as well as the brain, the heart beats more slowly, the breathing is more quiet, the temperature of the body is lower. The whole of your body does not go to sleep at one and the same time. First the eyes go to sleep, then the smell, then the taste, then the hearing, and last of all, the touch. When you wake your touch wakes first, then your hearing, taste, smell and sight in that order.

Death.—Parts of our bodies are dying all the time: the outer skin, for instance. It dies and is rubbed off. Parts are dying all the time and being revived all the time; the blood-corpuscles, for instance. They lose their oxygen, which is their life, but get new oxygen from the lungs. A very bad burn kills the arm and it may wither and die, though the rest of the body lives on very well without it. The whole body dies a natural death when the heart stops sending good blood, or when the lungs stop breathing. So long as the heart and lungs are doing their work the body is alive. When they stop, either through disease or as the result of some injury or violence, the body dies.

Decomposition.—The body is built up of chemical elements. So long as it is alive the *life* within us (whatever that may be—no one knows) has the wonderful power of making each element do some useful work in building up bone, muscle, fat, in making blood or tissue. When the *life* is gone, when the body is dead, the chemical substances of which it is made go back to form parts of the earth from which they originally came. Atoms that once formed part of Julius Cæsar's body were taken into the soil and may now be part of the clay of some vase in a collection of Roman pottery, or they may stop a hole in some workman's cabin to keep the wind away as Shakspeare has said:

> "Imperious Cæsar, dead and turned to clay,
> Might stop a hole to keep the wind away:
> Oh, that that earth, which kept the world in awe,
> Should patch a wall to expel the winter's flaw."

The Senses.—"The five senses" are sight, hearing, smell, taste, touch. There is at least one more

—the temperature-sense. You can tell whether a piece of iron is hotter than your hand without touching it and with your eyes shut. It is possible that birds and fish have special senses that men do not have. They seem to know their way home in cases where men would be quite lost.

We Know the Outside World Through Our Senses.—Things in the external world are known to us only through our senses. We see, hear and touch them. If we are blind or deaf we know much less than we otherwise should know. The nerves of sight, hearing, touch, bring messages from things in the world to our brain. Our brain thinks about these messages and decides what is to be done. If anything is to be done it sends messages to the muscles and they do it.

We often make wrong judgments about the messages that our senses send to the brain, as is proved by the experiments on page 346. It is not certain, then, that we always know the outside world correctly. Any one of us is much more certain about anything he hears or sees if he knows that some one else sees or hears it in the same way. The things in the outside world that we are most certain about are the ones that a very great number of people have seen and described a very great number of times.

Personality.—There is one thing that we know without asking anyone's help. Each one of us knows that he exists; that he is a person. So long as his mind and brain go on thinking, and reflecting about his thoughts, he is sure that *he* exists, any way. No other animal but man thinks about his own thoughts. A dog *may* notice that snow is white, besides being cold; that chalk is white, besides being hard; that milk is white, besides being good to drink. It is possible, though not likely, that when he is thinking of milk to drink he may remember that milk is white. But no dog ever imagined such a thing as *whiteness*, nor thought that milk, chalk and snow, different as they are in most respects, at least are alike in this one respect —namely of whiteness. Most animals are, in a large degree, machines—they act without thinking about their acts. Men also do many acts in a machine-like way. For instance if some one pretends to aim a blow at your eye, you wink—you cannot help doing it—although you know very well you are not going to be hit. If the inside lining of your nose is tickled with a feather you *have* to sneeze. You cannot help it any more than a locomotive can help going when the steam is turned on. When the *stimulus* (the exciting feather-touch) comes the action *must* follow. If an insect-eating plant is touched, even by a stick, it shuts its leaves with a snap. If an oyster feels anything floating over its open shell it shuts up whether the thing is good for food or not. If a fly lights on your forehead you brush it off even when you are asleep. You are like the lower animals in this machine-like response to a stimulus. But you are very different from them in your power to think, to remember your thoughts and to reflect about them; in your power to know what is honorable, what is good, and what is right. That kind of knowledge makes you a person, and it makes you *responsible*. If you have such powers it is your duty to use them rightly.

Cells. — If we keep on dividing any part of the body of an animal (or a plant) as long as possible we find, at last, that it is made of *cells*. A cell is a little box with walls, filled on the inside with living *protoplasm* (something like the white of egg). The bones, the tissues, the muscles, the blood, the nerves are made of small cells. The smallest are about $\frac{1}{3500}$ of an inch in diameter. Even the largest are very small. Each cell is alive, that is, the protoplasm inside it is alive. Many cells (as the white corpuscles of your blood — see page 327) can move and do grow by division just as the single-celled animal, the *Amœba*, moves and grows.[1] Every such cell grows; divides over and over again to make others; by and by decays; and finally dies. While it is alive it does work of some kind and takes food. If it is a muscle-cell it helps to build up muscle. If it a tissue-cell it builds up tissue. Sometimes, in case of need, a cell will take up work not its own. If, for instance, a muscle is injured, tissue cells will help to build it up.

The Human Body is a Colony of Cells. — The human body is something like a great colony or

[1] See Book VI, Zoölogy, page 188.

ant-hill of different kinds of cells each one working to help the colony to live and prosper. Some cells make food, others carry it where it is needed (the blood-cells), others build up bones and muscles, others transmit messages (the nerve-cells). In the spinal-cord there are committees of cells (nerve-centers) that manage all matters like breathing, sneezing, etc., without troubling the brain with such little things; and finally in the brain there are higher committees of cells (nerve-centers) each attending to its own work. One brain-committee attends to hearing, another to seeing, another to touching, and other committees help us to remember, to make judgments, to be affectionate or angry. A tree is something like a colony of coral animals.[1] The body of a man is a much more complicated colony — something like a great city with all kinds of persons in it, each kind doing one sort of useful work, and all working together to make the whole body healthy and strong.

The Human Will Governs the Body. — Back of all this there is your personality; the thing, whatever it is, that makes you *you* and not someone else. This can decide what is right, and *will* to do it. It can wish to do right. It can try, and if it fails one time, it can keep on trying. Your body, with all its wonderful arrangements, is, after all, of no special good unless it is directed by a will that means to do right — to be true, brave and kind. It

[1] See Book VII, Botany, page 246.

is *your* business to have that kind of a will: it is the business of your body to do what *you* tell it to do.

Seeing: The Eye.—

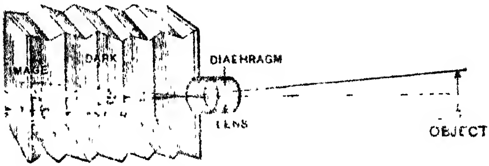


FIG. 314. How the image of an object is seen on the ground glass of a photographic camera. Rays of light from the arrow ⟶ pass through the lens of the camera, through the dark chamber, and make an *image* (see Book I., Astronomy, p. 12) on the ground glass.

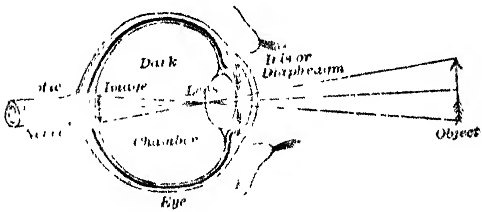


FIG. 315. How the image of an object is seen on the back part of the eye (on the *retina*) Rays of light from the arrow ⟶ pass through the lens of the eye, through the dark chamber of the eye and make an image on the *retina*. The retina is covered with nerves and these send messages to the brain "I am touched by light—by light of such a brightness and of such a color." The brain receives all these messages and makes up its mind what sort of a thing is seen. *It is the brain that does the real seeing, not the eye.* The eye only forms the image. The brain decides what it is.

Experiments.—Wipe the tongue dry and put a bit of sugar on the tip. It will not taste sweet till the sugar is dissolved.

Take two one-pound weights from a grocer's scales (both iron or both lead and of the same size). Heat one of them and leave the other one cold. The cold weight will seem the heavier.

Draw on a white card two squares of exactly the same size. Cover the surface of one of them with horizontal lines, and the surface of the outer with vertical lines. Which square looks the taller? Which the wider? (Try it.)

Draw two parallel lines ═══ about a quarter of an inch apart. Cross one of them with short lines like this \\\\ and the other with lines like this ////. The lines will no longer seem to be parallel. (Try it.)

Close your left eye and look steadily with your right eye at the left-hand dot, holding the book about twelve inches distant. Both dots will be seen. Move the book slowly toward your eye, which must be kept steadily fixed on the smaller dot. The other dot will disappear. Bring the book nearer and it will reappear. (Try this several times.)

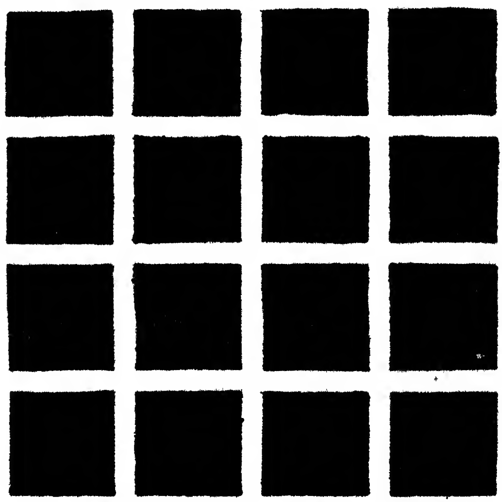


FIG. 316. Look at this picture and you will see that the white spaces at the corners of the black squares seem to have dusky spots in them. Look closely at any one of the dusky spots and it will disappear.

Cross your middle finger over your forefinger so as to leave a V-shaped space between their ends. Rub the ends of both fingers lightly against the very point of your nose. It will feel as if there were two points to your nose. (Try it several times.)

A bit of alum on the tip of the tongue tastes sour; on the back of the tongue sweetish. (Try it.)

The experiments just given show that your judgments about your sensations are not always right. The reasons for the mistakes of judgment are well known but need not be given here.

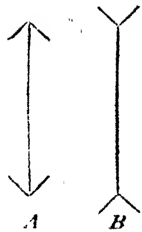


FIG. 317. Draw two lines *A B* of the *same* length. Put arrow-heads on *A* and arrow-tails on *B*. *B* will appear longer than *A*.

Hearing: The Ear.

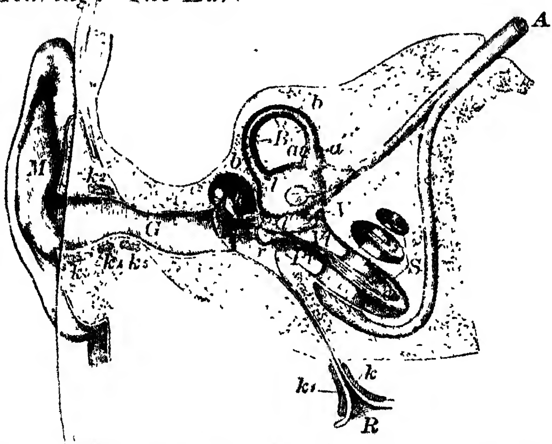


FIG. 318. The Ear: *M* the *shell* of the ear; *G* external tube which carries vibrating air to the *drum* (*T*). This vibrates and sets the air of the inner ear, as well as its little bones, to vibrating. The vibrations are carried by the nerve *A* to a particular part of the brain. *It is the brain that does the real hearing, not the ear.* *R* is a tube leading from each ear to the mouth.

Smell: the Nose.—The mucous membrane that lines the nostrils is the organ of smell. Nerves from each nostril run to the brain. A piece of camphor is all the while giving off little particles. Some of these touch the ends of small nerves in the nostrils and other nerves carry the news to the brain. *It is really the brain that does the smelling, not the nose.*

Taste: the Tongue.—The upper side of the tongue is covered with thousands of little elevations under which are nerves—sometimes nerves of touch, sometimes nerves of taste. When sugar is put on the tongue these nerves telegraph to the brain. *It is really the brain that tastes, not the tongue.* What we call tastes (flavors) are often not tastes but smells. Hold your nostrils tight and chew a piece of cinnamon. You will have a hot sensation but no *taste* till the nostrils are opened. (Try it.) Remember this when you have medicines to take. Hold your nostrils tight shut, and in most cases you can not taste what you are swallowing.